The Engineer

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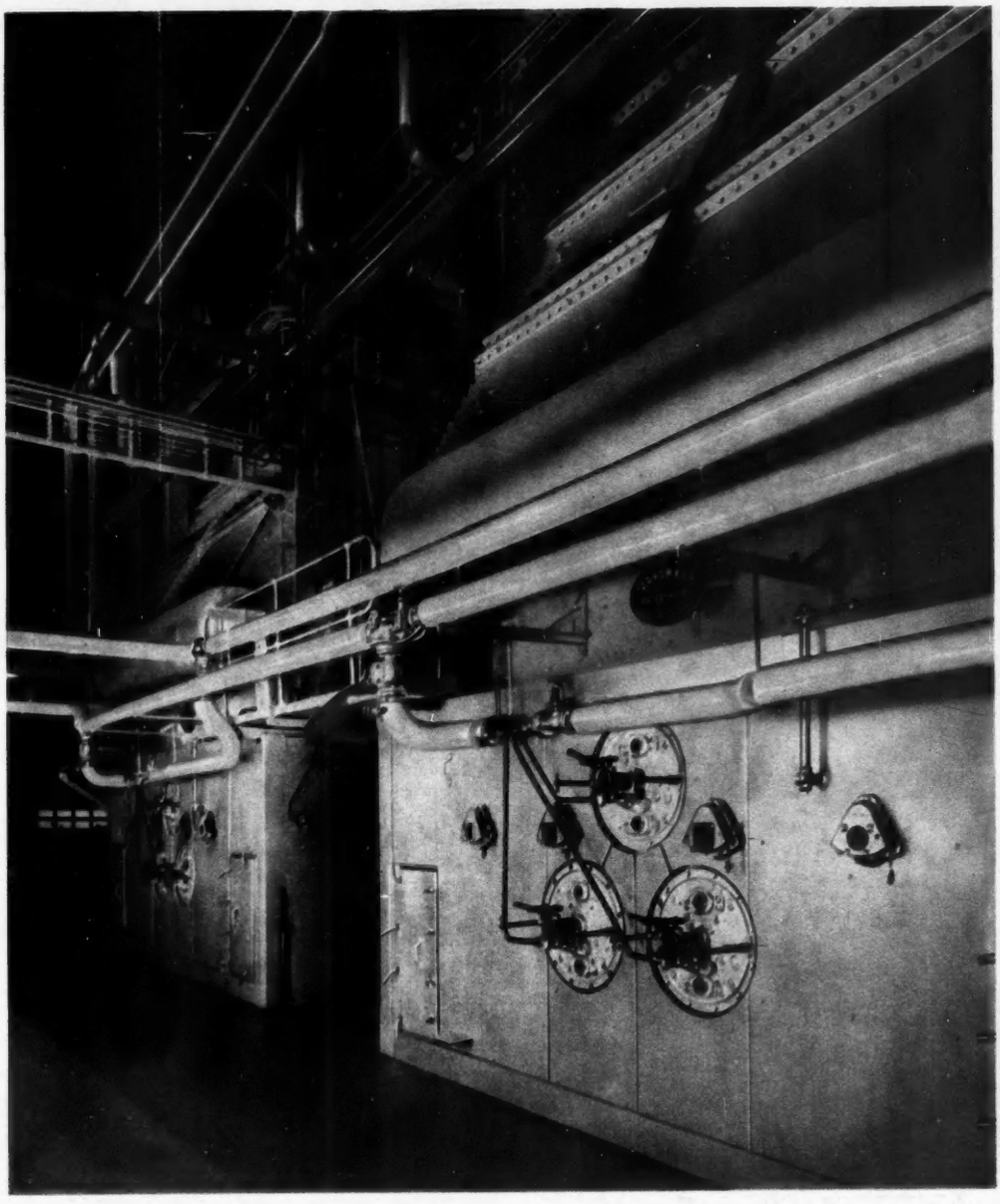

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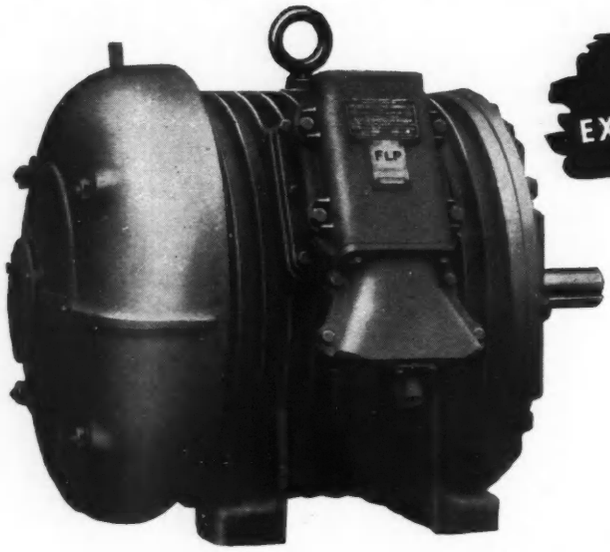

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THE ENGINEER

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WAGE NEGOTIATIONS AND PRODUCTIVITY

As we write the strikes in shipbuilding and engineering have been called off. Courts of Inquiry into the still existing disputes in those industries have opened. We do not intend, therefore, specifically to refer to any possible compromises that could bring the disputes to an end. But now that a settlement, it can be hoped, is in sight—for Courts of Inquiry have usually succeeded in bringing the two sides together—it is desirable to ask what it is that is wrong with negotiating machinery, and perhaps labour relations, which permits unions in other industries along with shipbuilding and engineering to claim and to receive annually increases of wages greater than can be justified by increases in productivity, why settlements are so seldom reached without, at least, threats of strike action, why unions object to any linking of wage rates with productivity and how it comes about that unions pay so very little attention to the raising of productivity—which must benefit their men—and so much more attention to increasing wages, which, in the absence of improved productivity, can only create inflation and thus fail to benefit their men ? In short, is it not time that union leaders linked wage claims to a real standard like productivity rather than to an ever-receding shadow like the cost of living?

Effectively, the present disputes in shipbuilding and engineering have turned upon factors which are as relevant to other industries as to these two. The employers, from the beginning, proved unwilling to grant any wage increase "*in vacuo*." But later they did prove willing to grant an increase provided there was a *quid pro quo* from the unions either in the form of a holiday from new claims for a twelve month or more (which would give time for improvements in productivity to take effect), or in the form of a relaxation of union restrictive practices and demarcation disputes which would take effect quickly in raising productivity. Without any such *quid pro quo* the employers clearly felt that it would be senseless to grant an increase. For, because the effect would be inflationary, the benefit to the workers could be transitory only and, because the cost of living would be increased, it could only serve to provide the unions with arguments for formulating yet another new wage claim within a few months. Meanwhile, costs of production would have been pushed up and the difficulty of competing in export markets would have been increased. Presumably, what the union leaders have in mind in pressing annual wage claims that they can hardly fail to realise are inflationary is that, though a part of the increased wage is swallowed up by an increase in living costs, some benefit is retained because the workers gain a larger slice of the national wealth. Certainly, this has proved the truth since the war. For union members almost alone amongst the population have improved their standards of living. But, at best, the method of achieving this result cannot be regarded as anything but crude, and clearly, being inflationary, it is not, in the longer term, in the interests of the men themselves any more than it is in the interests of the nation. Furthermore, with every year that passes it becomes less probable that it will succeed. For the professional and executive classes, those classes whose standards have already been substantially eroded, are beginning to react strongly. Within the engineering field, for example, there is so great a shortage of technologists and technicians and of men with the talents to hold executive jobs that salaries are rising sharply to attract younger men into industry. If wages rise these men are now demanding that their salaries, too, shall rise. The same reaction is apparent in the outspoken suggestions to the Chancellor that in next Tuesday's Budget there should be substantial reliefs for surtax payers. Indeed, unless British industry is ready to pay such men higher salaries and the Chancellor ready to relax taxation upon them—so short is the Western world as a whole of trained intelligent men—they will take posts abroad. Significantly, more such men than this country can afford to lose are already emigrating. The scope for union leaders to raise the standard of living of their followers by reducing that of other men is narrowing.

Since the war the unions have used various arguments to justify wage claims, such, for example, as the one that refers to unduly high profits ; but that argument has never been very effective as even the dispersion of the whole distributed profits amongst workpeople would have almost negligible effects upon wage rates. The basic justification has always in reality been an increase in the cost of living. Other arguments have always been subsidiary. Yet how sterile it is to link wages in this way to the cost of living ! Since there is a natural and human desire to

improve standards of living this linkage leads directly and inevitably to inflationary wage claims. Fortunately, there is an alternative. It is the alternative which the employers favour, but which the unions as a whole (with the notable, though perhaps only apparent, exception of the N.U.R.) are resisting. It is to link wages not to the cost of living, but to productivity. There are obvious difficulties ; for productivity is not easily measured. Yet it may well be asked whether the crude national figure which could easily be calculated would prove any cruder than our present cost-of-living index, of which the unions are themselves critical, in providing a standard. Alternatively, similarly crude figures might be applied with possible advantage to individual industries. The advantages of weaning unions away from basing claims upon the cost of living on to the much more real ground of basing them upon productivity are many. There would, for example, be less reason for employers to resist claims that were pitched somewhat high in the first place, because no further wage claim could thereafter be justified until the productivity index had risen proportionately. Furthermore, the unions having pitched a wage claim high would necessarily come to be interested in proving that it was, in fact, justified, in order to have grounds for a new claim. Something akin to this reaction already occurs in the United States where the unions actively support managements in the effort to raise output.

What chances, we wonder, are there of bringing about so beneficial a change of attitude ? To hope for it overnight is clearly absurd. For years unions have been basing wage claims primarily upon the cost of living. For years they have regarded productivity as primarily the business of management ; they have thought of mechanisation as the answer by which managements compensated for higher wages ; they have thought of the pressure for increased wages as a means of forcing less efficient managements to adopt improved methods. Simultaneously and paradoxically, out of long memories about the miseries of unemployment, they have imposed restrictions which have actively discouraged managements from introducing labour-saving machinery, and have pressed inter-union rivalries so far in demarcation disputes as to discourage managements from introducing new materials and improved production methods. The old and out-dated idea still persists amongst some leaders and many men that the object of a union is to wring out of unwilling managements as much as possible in the way of wages and conditions of work and yield as little as possible in return. Fortunately, this idea is far from universal. Individual firms, particularly in the engineering field, even a whole industry here and there, have managed to establish more satisfactory relationships with their men. It is also true, we think, that many union leaders would like to see unions more actively participating with managements in raising the prosperity of industry, a situation which, they realise, would rapidly benefit their men. But amongst working men, more particularly in industries that suffered severely during the inter-war depression, the old tradition dies hard. Deep suspicion of " the boss " persists. Yet whatever the outcome of the present disputes in shipbuilding and engineering, it is impossible to believe that there can be an exact return to the *status quo ante*. The employers have demonstrated forcibly their dislike for the granting or even the negotiation of wage increases *in vacuo* and without reference to aid from the unions in raising productivity. No doubt upon this occasion a settlement will be reached by compromise. But notice has been served upon the unions that matters affecting productivity will necessarily have to be brought into future discussions. For we have no doubt that unless they are employers will again stand firm.

HIGH M.E.P.—LOW REVS

We report on page 540 a series of trials devoted to an object esteemed by every mechanical engineer—reducing the losses in the transmission of dearly bought shaft horsepower in motor vehicles. The medium in this case was an oil additive, and there appeared to be a certain improvement—small, but hardly to be denied, and particularly welcome to any designer grappling with the problem of cooling lubricant confined to a small and arbitrarily located sump. When one reflects that the viscosity of the oil, and, hence, the toll taken of all the energy passing, is determined by the need to carry a peak load of rare occurrence, there will be few ready to claim that cheap oil represents an economy.

But there is little room for manœuvre in economising in fuel through improvement in mechanical efficiency. Much larger economies could be realised if thermal efficiencies were raised. The fuel consumptions of private cars with carburetted engines vary widely, and since the limitations of thermodynamics are strict, it follows that the efficiencies must depart far from the ideal. The pronounced and singular indifference of the road transport engineer in this country to the use of chassis dynamometers measuring the power at the road wheels, renders it difficult to assign absolute values to the efficiency of typical vehicles. But even without this knowledge one conclusion emerges : for economy, and probably also for reliability and endurance, the engine's mean effective pressure should be high and its revolutions per minute low. That the gear ratio is more important than engine design in this matter we have shown to the satisfaction of ourselves and the surprise of many drivers. Using the Ford 1172 c.c. side-valve engine, but with a back axle ratio 15 per cent higher than usual, it was possible to combine high average speeds with 32 ton-mile per gallon outputs over many thousand miles. But this performance involved also, of course, correspondingly more concentration and effort from the operator, more than the ordinary driver would be prepared to accept.

A customer who is attracted by the possibility of ranging between 8 and 80, or 9 and 90 m.p.h. in top gear cannot be easily provided with the benefits that could be reaped from an engine working at high mean effective pressures for most of its life. The engineer has come, by long and ill-custom, to accept that the accelerator should belie its name and, in fact, control a throttle. In fact, it should control engine or, better, vehicle speed. Certain it seems that the transmission will sooner or later cease to include the " crash " gear even though its brutality be mitigated by synchromesh. " *C'est brutale et qui ne marche pas* " is becoming the response of advanced designers to Panhard. They seek some automatic control to mediate between the engine and the driver. The problem is unlikely to daunt the designers of the second half of the twentieth century. Some engineers in this country have already had experience of an Italian hydrostatic gearbox which gives an even more rapid variation of ratio than is welcome on a lightly loaded motor-cycle. That transmission has been run in a form giving a continuous unbroken line on the speed/torque characteristic of the engine, and could doubtless be made to answer to a true accelerator instead of a throttle. A further difficulty may well arise. The four-cylinder engines popular in this country to-day would, we fear, be regarded as intolerably rough, pulling hard at low revolutions. No one to-day wants a car with that characteristic of the model " T " Ford ! However, the manufacturers of commercial vehicles still glory in petrol engines that lie quietly on only the thinnest of rubber cushions, and the motor-cycle industry has a long saga of success with hemispherical combustion chambers that provide knock resistance at low speeds and volumetric efficiency at high, so that a wide working speed range at high mean effective pressure is within our grasp. To evolve a transmission that will unfailingly find the optimum operating point in that range is, without question, an ambitious, even idealistic, programme in the face of high capital charges and uncertain fuel costs. But, surely, one thing need not wait—an end to a fuel system that allows the engine to consume fuel even when it is being used as a brake !

A Seven Day Journal

Atomic Energy Exhibition for Australia

A MOBILE exhibition designed to show the useful application, progress and development of atomic energy in Britain has been organised by the Board of Trade in conjunction with the United Kingdom Atomic Energy Authority. The exhibition is to make a tour of a number of the principal cities in Australia to show in particular the very advanced work carried out by this country in the production of electric power by means of atomic reactors. It includes a number of panels of interesting photographs and diagrams, and models of the Calder Hall and Dounreay reactors, illustrating by means of illumination how they operate. The exhibition shows that the United Kingdom Atomic Energy Authority has, in addition to Harwell, some fourteen factories and research establishments in Britain, and indicates some of the work they do. The twelve different kinds of research reactor now in operation or in process of construction are also briefly explained. Some indication is given of the way in which Britain is collaborating with other nations in the development of nuclear power, and how in connection with this work in Australia a number of scientists are being trained here, as well as assistance given in the production of a reactor for research in Australia. The exhibition will first be shown at the Sydney Industries Fair and later at Melbourne, Canberra, Perth, Adelaide and Brisbane, and it will be accompanied by a representative of the Atomic Energy Authority who will be available to answer any questions.

Electric Locomotives Ordered for British Railways

CONTRACTS have been placed by the British Transport Commission for sixty complete main line locomotives and for forty electric equipments, to be used on electric locomotives to be built in British Railway workshops. The value of the contracts is about £6,000,000 and the locomotives are primarily intended for use on the Crewe–Manchester and the Crewe–Liverpool lines, forming part of the electrification programme on the London Midland Region. The two mixed traffic design locomotives ordered are of the types A and B. The type A locomotives are intended for hauling express passenger trains of up to 475 tons at speeds up to 100 m.p.h., or mineral trains of 950 tons at 55 m.p.h. The type B locomotives will have a maximum speed of 80 m.p.h. and will be capable of hauling mineral trains of up to 1250 tons at 55 m.p.h. Both types of locomotive will have a continuous rating of 3300 h.p. and their difference will be in their gear ratios. They will have a B_0-B_0 wheel arrangement with an axle loading of 20 tons, and be suitable for operation in all regions of British Railways. Extensive standardisation of parts is being introduced for the locomotives, including the fitting of standard pantographs and circuit breakers and the identical layout of the driving cabs. The locomotives will be operated on the 25,000V, 50 cycle a.c. system, and their d.c. traction motors will employ direct current supplied by transformers and rectifiers, with speed control by tap-changing. The possibility is being considered of using germanium rectifiers on some of the locomotives to be supplied by B.T-H. Under the contract twenty type A and five type B locomotives and forty electrical equipments are to be supplied by the British Thomson-Houston Company, Ltd.; ten type A and five type B by the English Electric Company, Ltd.; five type A and five type B by The General Electric Company, Ltd., and five type A and five type B by Metropolitan-Vickers Electrical Company, Ltd.

Trans-Iranian Pipeline

A FILM, in colour, has been made by Costain-John Brown, Ltd., depicting the design and construction of an oil pipeline which that company recently undertook in Iran. The pipeline runs from Abadan to Teheran, the capital, a distance of 700 miles, and the section undertaken by Costain-John Brown, Ltd., together with the company's American associate, Williams Brothers, Ltd., was 300 miles in length, the value of the work being £6,500,000. The line crossed, first, a desert plain where temperatures in the shade varied between 130 deg. and freezing point, and then part of the Zagros mountain range, where it reached a height of nearly 2000ft. The line was laid at an average speed of 1½ miles a day. The construction of four pumping stations was also involved. The work was finished in twenty months. From Azna to Teheran—another 270-mile stretch—the pipeline, with one pumping station, is being laid by a French company. The section between Abadan and Ahwaz had been in existence for some time. Although only six pumping stations are required in the pipeline at present, thirteen pumping stations are planned for its final phase, when the throughput will be increased to 2,000,000 tons a year. All plant and equipment had to be delivered to Persia within six months with 28,000 tons of pipe, engines, pumps and other permanent equipment to follow within twelve months. The piping was of high-tensile steel with a 10in nominal bore and was cut to 40ft lengths with ends bevelled for welding. The Zagros mountains presented the most difficult obstacle to the pipeline and in the Kashgan River gorge the river had to be crossed and recrossed in twenty-seven places; often the only available location lay in the road itself, which had been carved out of one side of the gorge and which was no wider than 18ft at times; gradients of one in three were encountered. The actual pipelaying operation—the "main spread"—followed some distance behind the excavating teams and was composed of the conventional units used in this class of work. Tractors, with side booms, were responsible for "cold bending" the pipe sections to fit the contours of the trench. As each section of the pipeline was welded into a continuous length the line was tested with gamma rays first for any fault in the welding. Every section was then tested with air pressure and finally hydraulically under high pressure. The pipe was cleaned by a machine, equipped with a combination of cutters and wire brushes, which was supported by the pipe and moved along it under its own power. A thin coal tar base primer coating was applied before a second machine coated the pipe with a layer of coal tar enamel, into which was spirally wrapped a fibre glass tissue or thick "Kraft" paper. In rocky country additional protection was given by overlaying the fibre glass with a special wrap of "Thermoglas." Inspection of the coating was carried out by an electrical detector. In crossing rivers the trenches had to be dug "in the wet." The pipe sections were bent and joined to match the shape of the river bed, and the pipe was then swung out over the river and lowered into the trench.

The Engineer
100 Years Ago
(APRIL 3, 1857)

"STEAM CULTURE—ROPE TRACTION"

"What is the tear and wear of a wire rope in ploughing an acre of land, the moving power being steam? We ought now to be receiving practical information on this head, so as to guide our ratiocinations for the future. Given the resistance of the implement in turning up or loosening the soil to a certain depth, the weight of the wire rope, its velocity and friction on the ground, the number and diameter of the pulleys over which the rope passes, the angle which it makes in thus passing over pulleys, and the force of traction required to work the whole; required, the tear and wear of the rope. We have now, for example, several steam ploughs at work on the rope-traction principle—where the dimensions of the furrow slice or depth of culture are known, and force of traction required to overcome the resistance, with the steam force applied, as well as all the other conditions at issue. What is the tear and wear or expense of the wire rope per acre? In other words, what does the wire rope cost and how many acres can be cultivated by means of one rope. . . . . .

"It may be said that the force of traction required to haul the implement, deducted from the force of steam required to move the whole, would give an approximate estimate of the amount of friction; but although the rule may be useful it is subject to many objections, being, in point of fact, far from correct. But even granting it were correct, we have had no experiments with dynamometers to give the force applied to the one end of the rope nearest the engine, and the force of traction at the other end of the rope applied to the implement; and until we have such it would be superfluous to mention other objections."

Civil Engineering Contributions to Shipbuilding

THE meeting of the Institution of Engineers and Shipbuilders in Scotland, held in Glasgow on March 26, was devoted to the discussion of a paper by Messrs. Paton and Geddes with the above title. The authors pointed out that the last decade had seen a very decided evolution in shipbuilding methods involving the prefabrication and handling of much larger units. Reconstruction of shipyards to meet these changing conditions had no doubt been accelerated by world competition, but there had been few opportunities in recent times for the construction of new yards. The problems of maintaining yards in service while reconstruction was proceeding were at times much greater than normal design problems, the authors pointed out, and the civil engineer's work required corresponding ingenuity. The impressive changes in shipbuilding methods had, however, more or less coincided with quite major developments in civil engineering, and capacities of plant, foundations and so on had increased. One of the most valuable contributions the civil engineer could make, it was stated, was a proper assessment of ground conditions based on soil mechanics investigation. The planning of a modern shipyard required no less consideration than the layout of a motor vehicle or aircraft assembly plant. Several detailed descriptions of the civil engineer's contribution to work of this kind were given in the paper; they referred to such subjects as providing crane "coverage" and foundations for cranes, the layout of shipbuilding berths, dry dock regions, and, of course, soil mechanics problems.

Atomisation of Water by Spinning Discs

By J. R. PATTISON, B.Sc., D.I.C., Ph.D., A.Inst.P., and J. D. ALDRIDGE

A study of the characteristics of water sprays produced by spinning discs of various designs has been made, and information on the mechanism of droplet formation has been obtained. Grooved discs with flat annuli prevent surface slip, but do not reproduce the atomisation processes occurring on plane discs. However, vaned discs which also prevent slip appear to give fairly homogeneous sprays by the break-up of small filaments at the disc edge in the same way as plane discs. The simple formulæ of Bär relating droplet diameter to liquid and disc parameters are discussed and shown to represent an over-simplification of the drop formation process. A qualititative explanation is given for the drop spectra obtained.

THE atomisation of a liquid into small droplets may be carried out by forcing it through a nozzle into still air or by impinging a rapidly moving gas stream on to the liquid in a two-fluid nozzle. In both these processes high pressures are used to drive the liquid out of the nozzle so that it is inevitable that a velocity gradient will be set up across the nozzle aperture. Hence, since the conditions at the orifice are not uniform, a uniformity in droplet size or droplet velocity is impossible. Where a spinning disc is used to accelerate a liquid to a high velocity and discharge it from the disc edge in the form of droplets, no high pressures are involved and the formation of homogeneous sprays is apparently more attainable.

If a homogeneous spray of water droplets with constant high initial velocities is required the spinning disc appears to offer the most attractive method of production, but published information on the droplet diameter spectrum to be expected from simple disc designs under given conditions of operation is scanty.

Methods of Droplet Measurement

The available methods for the sizing of liquid drops may be classified as direct or indirect. The direct methods to be considered involve the capture of droplets in various cells containing oils and greases. The "drifilm" method employs a water-repellent film of a silicone as the coating at the bottom of a glass cell. The cell contains a non-viscous liquid of lower density than the spray, in which the spray drops do not mix. The drops caught in the cell sink to the bottom, where they remain almost spherical. In the two oil variant of this technique, two oils immiscible with each other and the spray are used in a cell. The densities of the oils are so chosen that the droplets remain suspended at the interface. The disadvantage of both methods is the tendency of the drops to coalesce when the cell is moved.

Another direct method involves the impact of the drops on a slide coated with a viscous grease mixture. After the drop sample has been taken, this slide is covered with another, coated with a similar grease in the molten state. In this way the drops are embedded in the grease between the two slides. The disadvantages of this method are the manipulative skill required and the correction that must be applied for the rapid evaporation of the drops subsequent to capture. The indirect measurement of droplet sizes depends on either arranging that the drops mark a surface in a characteristic way, or replacing the liquid which is atomised into drops by a hot wax which solidifies after atomisation. The resulting pellets may subsequently be graded by sieving. This wax method, described by Joyce[1] is not applicable to a spinning disc water spray without great experimental difficulty and without exact knowledge of the effect of the properties of the liquid on the mechanism of drop formation.

Indirect measurements of droplet sizes from a mark produced on a suitable surface require a knowledge of the relationship between the mark and the actual drop size. Courshee and Byass[2] have developed a technique where stains from a suitably dyed aqueous spray are obtained on a specially treated microscope slide. The relation between the stain size and the drop causing it was evaluated by sampling a given spray with the prepared slides and by the method of impact on grease. The evaporation which causes inaccuracy in the latter method was corrected for by using previously determined rates of evaporation[3] of the drops. This stain sampling technique is unsuitable for the investigation of sprays, since the stain size depends on the velocity of the drop causing it. Thus an already involved calibration procedure would be further complicated by the necessity to take varying velocities into account.

The crater formed when a liquid drop impinges on to a thin layer of magnesium oxide provides an indirect measure of the actual size of the drop. The relationship between drop and crater, as described by May,[4] is simple; the crater diameter is 1·16 times the drop diameter. The high velocities of the droplets produced by a rotating disc are an advantage rather than a disadvantage, since the higher the velocity, the more exact is the relationship between the crater and drop diameter. The only disadvantage appears to be the requirement that the droplet should strike the surface of the oxide layer normally.

Description of the Sizing Method Investigated

The magnesium oxide crater method appeared to be the most promising of those described above. Before this was adopted, a preliminary investigation of its practicability was carried out. The oxide layer was deposited on to clean microscope slides by passing them over a burning magnesium ribbon. It was possible to obtain a smooth texture of the required thickness, which must be greater than the diameter of the largest droplet, provided the spluttering flame was not brought into contact with the slide.

A cascade impactor with a suitable shutter over the entrance slot was used as a slide holder. Air was drawn through the impactor at a constant rate by means of a critical pressure orifice and a suction pump connected to the exit tube of the impactor. The rapid air flow ensured that most of the drops impinged normally on to the slides, but only the first two were used since magnesium oxide layers on the third and fourth slides would have been destroyed by the air jets. The number of craters obtained on the second slide was very small, in comparison with the number on the first slide, so that it is unlikely that the third and fourth slides would show craters if it were possible to use them.

The operation of the impactor was tested using a disc revolving in a horizontal plane and fed with water at a constant rate. It was found that sharply defined symmetrical craters were obtainable without great difficulty provided that the time of exposure was sufficiently short to avoid swamping. The slides were observed by transmitted light in a microscope with a linear magnification ×100 and the craters, appearing as white circles on a dark background, were sized using the eyepiece graticule. Courshee and Byass[2] encountered difficulties with this method in that most of their drops entered the oxide layer obliquely or bounced off. The non-uniform craters formed in this way involved a smaller percentage of the sample with the high-speed spinning disc, probably because the drops were moving at

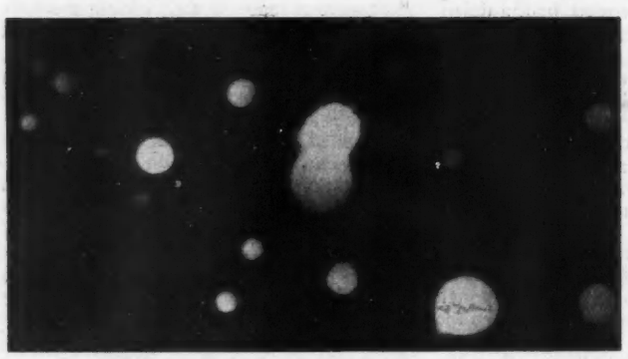

Fig. 1—Typical craters in a magnesium oxide layer, magnification × 180

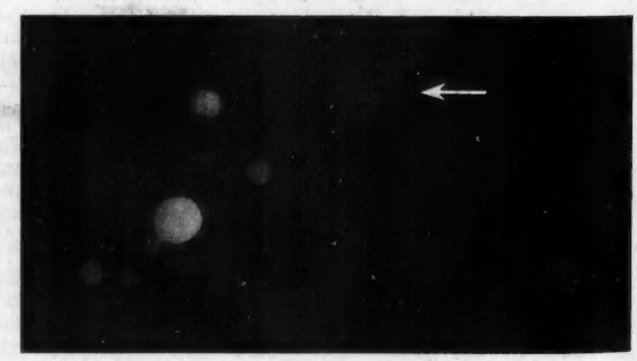

Fig. 2—Shallow crater produced by a bouncing droplet (indicated by arrow) magnification × 180

higher velocities and directed straight into the impactor slot. A few marks produced by drops entering the oxide obliquely were observed on the slides, but these were not included in the final analysis. It was, however, checked that oblique craters from droplets of all sizes in the range were present so that their omission does not weight the final totals unfairly. Fig. 1 shows a typical collection of craters, and Fig. 2 illustrates one of the faint impressions caused, according to May,[5] by the impact of a bouncing droplet. A relatively small number of these shallow craters were observed and they were excluded from the droplet summation.

The slides were examined using a travelling microscope and comparison of the size distribution curves from different slides obtained under the same conditions of droplet formation showed very good agreement. The method of visual counting under a microscope is, however, tedious and time consuming, so automatic methods of counting and sizing were investigated. A random scattering of droplets may be counted and sized by automatic methods in a number of ways, as described by Walton.[6] In general, scanning is carried out by a photocell and light beam arrangement to produce electronic pulses related to the size and position of the droplets. Various electronic systems have been devised to analyse and record these pulses, but all of them are more involved than was warranted by the range of the present investigation. One of the advantages of an automatic scanner is the elimination of the personal bias of a human observer. However, given a working scanning instrument, the preparation of a suitable record for scanning is difficult and may introduce more inaccuracy than is involved in visual counting with a microscope. Rupe[7] and Adler[8] used a "drifilm" technique, assuming that the droplets remained in spherical form, and obtained images on a photographic negative for scanning. Trickett and Courshee[9] used an enlarged photographic reproduction of the stains left on a glass slide by dyed droplets. The calibration of stain size against droplet size was made by using a grease impactor method as a control.

The electronic systems involved in automatic scanning techniques and the extra calibration and photography of the sample necessary are a high price to pay for the guarantee that errors due to human observations have been eliminated. Using the simple magnesium oxide crater method with two independent observers, the agreement in the distribution curves obtained was so close that further complication of the technique was not justified.

Grooved Discs

The first type of disc to be investigated was a grooved disc designed to prevent slip occurring between the water and the disc surface. The disc, illustrated in Fig. 3, had seventy-two radial grooves to convey water from an axial cup at the centre to the circumference of a 14in diameter circle, where it was intended that the water should spread evenly over a smooth annulus 1in wide.

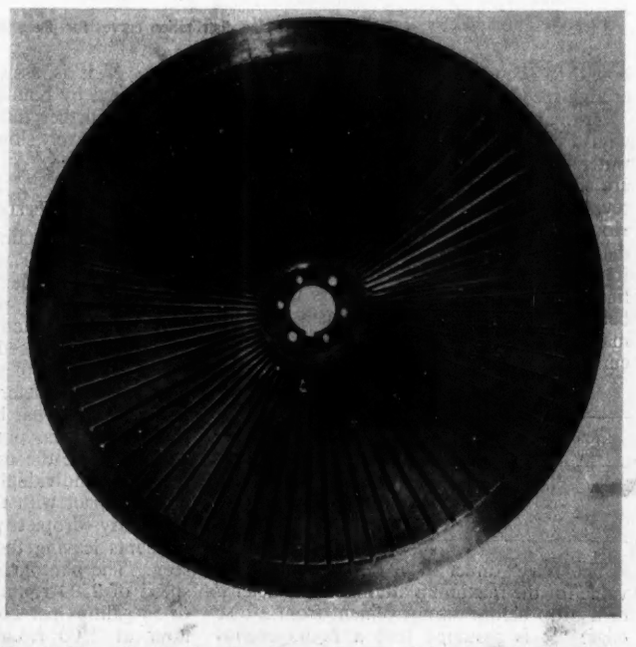

Fig. 3—Disc of 14in diameter with seventy-two radial grooves to prevent slip

The disc was mounted to revolve in a horizontal plane with water fed into the central cup from a perforated ring pipe in such a way that it was evenly distributed around the axis. At a speed of 4000 r.p.m. and with a water feed rate of 50 gallons per hour the characteristic spray size pattern found was that illustrated by Fig. 4. Superficially, this distribution pattern of percentage numbers of droplets in bands of different drop diameters indicates a homogeneous spray of 10 to 50μ diameter drops with a small "tail" of larger drops. However, a distribution curve of the percentage volume of water in each drop diameter band, as shown in Fig. 5, reveals the large proportion of the total water supply that is absorbed in this "tail."

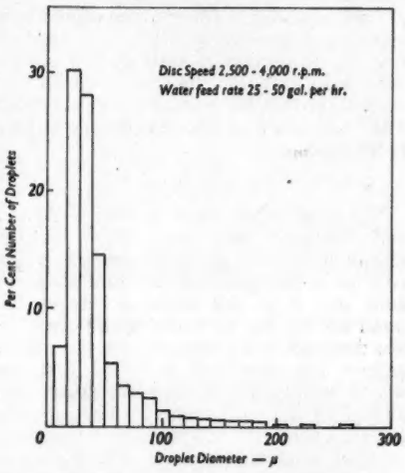

Fig. 4—Droplet size distribution curve for grooved disc

The mechanism by which droplets are produced by a revolving disc could involve three processes :

(*a*) Direct drop formation at the disc edge by the action of centrifugal forces in overcoming the surface forces holding the liquid.

(*b*) The formation of a film or of ligaments which are broken up into drops by the impact and friction of the liquid with the surrounding atmosphere.

(*c*) Atomisation, subsequent to a drop leaving the disc, which is brought about by the interaction of the internal velocity gradients and the surface tension of the drop.

It is usual to assume that "direct drop" formation occurs at the periphery of a revolving disc and therefore equating surface and centrifugal forces it would be expected that

$$d \propto \frac{1}{n}\left(\frac{\sigma}{r\rho}\right)^{\frac{1}{3}},$$

where

d is the maximum droplet diameter,
n is the speed of revolution of the disc,
σ is the surface tension of the liquid,
r is the radius of the disc,
ρ is the density of the liquid.

From experiments on spinning discs carried out by Bär[10] an empirical constant relating the two sides of the proportionality was determined

$$d=\frac{0{\cdot}525}{n}\left(\frac{\sigma}{r\rho}\right)^{\frac{1}{3}} \quad . \quad . \quad . \quad (1)$$

An evaluation of d from this expression, using values applicable to the experiment described above, gives a value of 149 microns.

Walton and Prewett[11] carried out experiments with spinning discs and empirically derived a different constant for Bär's equation. For water at flow rates low enough to ensure "direct drop" formation from an 8cm diameter disc, the constant is 0·315,

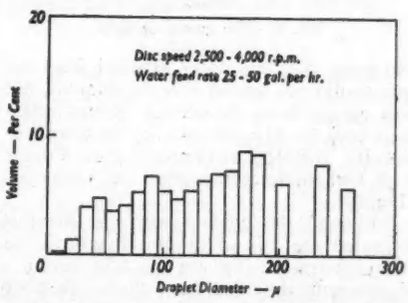

Fig. 5—Volume distribution curve for grooved disc

which, for the grooved disc, leads to a value of 89 microns for d. Boshoff[12] found the constant to be nearer 1·1, which gives a value of 312 microns, but Muraszew suggested an error in the droplet size measurements, which, if corrected for, would lead to a value for the constant more in agreement with Walton and Prewett's value.

By dimensional analysis and an experimental study of centrifugal disc atomisers Friedmann[13] derived a more complex equation,

$$d=kr\left(\frac{\Gamma}{\rho n r^2}\right)^{0{\cdot}6}\left(\frac{\mu}{\Gamma}\right)^{0{\cdot}2}\left(\frac{\rho\sigma l}{\Gamma^2}\right)^{0{\cdot}1} \quad . \quad (2)$$

where T is the flow rate of liquid per unit length of the wetted periphery of the disc, μ is the viscosity of the liquid, l is the length of the wetted periphery and the other symbols are defined for equation (1). The constant k is evaluated as 1·2 from Friedmann's experimental data combined with those of Walton and Prewett. For the grooved disc under investigation the equation gives a value for d of 170 microns.

Although the numerical constants in the equations (1) and (2) appear to be somewhat non-reproducible, there was a possibility that the general forms of these equations could apply to the drop formation from spinning discs, but the empirical constant was a function of disc size and form. The increased diameter of the disc under investigation compared with those used by Walton and Prewett,

and the consequent increase in peripheral velocity could require some modification of these equations. However, if the mechanism of drop formation was not "direct" due to the high flow rate of water or the failure of the water issuing from the grooves to spread over the annular ring, then equations (1) and (2) are not applicable.

Further sampling was carried out using a feed rate of 25 gallons per hour at the same speed of 4000 r.p.m., and both 25 and 50 gallons per hour were used at a speed of 2500 r.p.m. The histograms of drop size distribution obtained in these experiments were not significantly different from that illustrated in Fig. 4. Since the drop spectrum from the grooved disc was not markedly dependent on changes of the water feed rate or rate of revolution at the particular levels used, a different mechanism of drop formation from the "direct" one was indicated.

It was assumed that, because the groove cross-section had the shape of a trapezium (Fig. 6*a*) with only one point of contact with

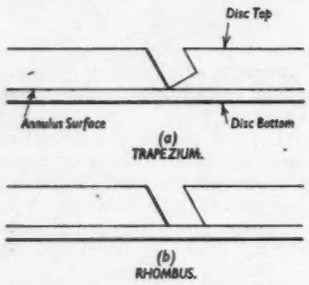

Fig. 6—Disc groove sections

the outer rim, the water expelled from the groove did not spread over the annulus, but was ejected from the disc in streams which were broken up into droplets by the surrounding air. Therefore an improved groove shape with a rhombic cross-section was employed (Fig. 6*b*).

Although the contact with the annulus extended the full width of the groove the drop spectra obtained for this type were not significantly different from those given by the first type. Observations of the rotating disc under a stroboscope lamp confirmed that little wetting of the periphery was occurring and indicated that water was leaving the disc in the form of jets. In order to confirm the hypothesis that the mechanism of droplet formation from grooved discs was essentially the disruption of water jets in the surrounding air, the annulus was machined-off a disc so that the grooves terminated at the edge of a 14in diameter disc. Investigation of the drops from this disc showed the same spectrum as before and the same insensitivity to changes in the rate of revolution and water feed rate.

Bär investigated the atomisation of water by rotating radial tubes and obtained the following equation for the maximum drop diameter :

$$d = \frac{0{\cdot}102\sigma}{n^2 r^2 \rho_a} \quad . \quad . \quad . \quad . \quad (3)$$

where ρ_a is the density of air and the other symbols are as in equation (1). This equation expresses the condition that atomisation by "velocity spraying" is produced by air resistance overcoming surface tension forces and that the maximum possible drop diameter depends upon a critical value of the Weber number. For the grooved discs under investigation, taking r as 7in, the values for d yielded by equation (3) are 41 microns at 4000 r.p.m. and 105 microns at 2500 r.p.m. The inapplicability of this equation and the concept of "velocity spraying" to grooved discs is demonstrated by the failure of the change of the speed of revolution n from 2500 r.p.m. to 4000 r.p.m. to produce a detectable modification of the droplet distribution curve.

The magnesium oxide coated slides were held in an impactor through which air was drawn at a constant rate to ensure that most of the droplets impinged normally on to the slides. A small proportion of the craters formed by spray from grooved discs were shallow, as illustrated in Fig. 2. This type of crater is stated by May[5] to be caused by a bouncing high-velocity drop, but the fact that the proportion of such shallow craters increased greatly for grooved discs when the suction through the impactor was dispensed with indicates that low velocity drops may be involved.

Plane Discs

The formulæ published by Bär,[10] Walton and Prewett[11] and others[12] [13] for the maximum droplet diameter formed at the edge of a flat spinning disc were stated to hold only if no slip occurred between the water and the disc surface. The grooved disc was designed to eliminate slip, but the investigations just described indicated that the whole mechanism of drop formation was altered by this modification. The performance of a plane disc was therefore investigated in order to assess the effect of slip which is bound to occur on large flat discs revolving at high speeds.

Histograms obtained by droplet sizing with a plane disc 16in in diameter, fed with water in the same way as the grooved disc, are shown in Fig. 7 for the same speeds of revolution and water feed rates used previously. From these diagrams the droplet diameter corresponding to the mode of the frequency curve may be found, but the mean linear values of droplet diameters tabulated below can be evaluated more easily without making assumptions about the form of the curves.

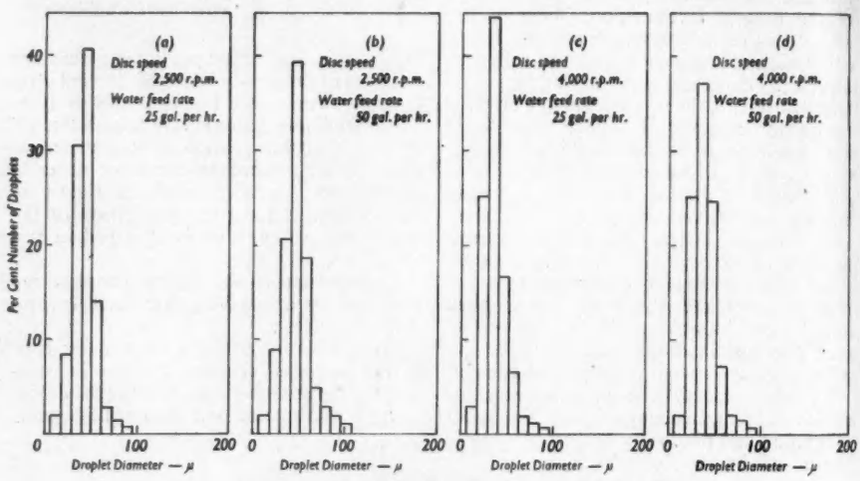

Fig. 7—Droplet size distribution curves for plane disc

Table I—*Mean Droplet Diameter*

Speed of revolution of plane disc, r.p.m.	Water feed rate, gallons per hour	Mean linear droplet diameter D
2500	25	42μ
2500	50	46μ
4000	25	35μ
4000	50	37μ

The Bär "direct drop" formula gives a value for the maximum attainable diameter d of a drop before disengagement from a disc edge. It is assumed that a homogeneous spray is formed consisting of drops of this diameter apart from a few satellites of much smaller diameter found by Walton and Prewett. At the speeds and flow rates under investigation it is apparent that this formula represents an over-simplification of the mechanism of droplet formation. The mean droplet diameter D tabulated above provides a more practical comparative figure. A statistical analysis of the droplet families showed that the differences produced by the feed rates and the speed of revolution were significant. The figures in Table I indicate an inverse relation between D and the speed of revolution, but not a linear one. The effect of increased water rate is probably confined to increasing the amount of slip taking place and since this reduces the speed of the water droplets below that of the disc edge it may be equivalent to a reduction in disc speed.

When the disc was viewed under the illumination from a stroboscope, stationary water waves were observed curving back from the water impeller to the disc edge in the opposite direction to the disc motion. At 4000 r.p.m. each wave occupied a sector of about one-quarter of the disc and at 2500 r.p.m. a slightly shorter slip wave could be observed.

The proportion of shallow craters on the magnesium oxide layers, obtained when air suction through the impactor was cut off, was greater than that found for the grooved discs. If it is assumed that these craters are formed by bouncing low velocity drops, this is a further indication of the presence of comparatively slowly moving drops resulting from slip.

High-Speed Photography

In order to obtain a more precise idea of the mechanism of water droplet formation from the discs under investigation, a number of short-exposure photographs were taken of the discs in action using a microflash. These are reproduced in Figs. 8, 9 and 10.

The water droplet formation at the edge of a 16in diameter disc, grooved to the inside edge of a flat 1in annulus, is illustrated in Fig. 8. The predominating mechanism appears to be the break up of jets of water from the individual grooves into droplets under impact with the surrounding air, but secondary droplet production from small filaments leaving the disc edge can also be seen. The photograph was taken for a disc speed of 2500 r.p.m. and a water feed rate of 50 gallons per hour. For 25 gallons per hour at 2500 r.p.m. and 25 gallons and 50 gallons per hour at 4000 r.p.m., similar

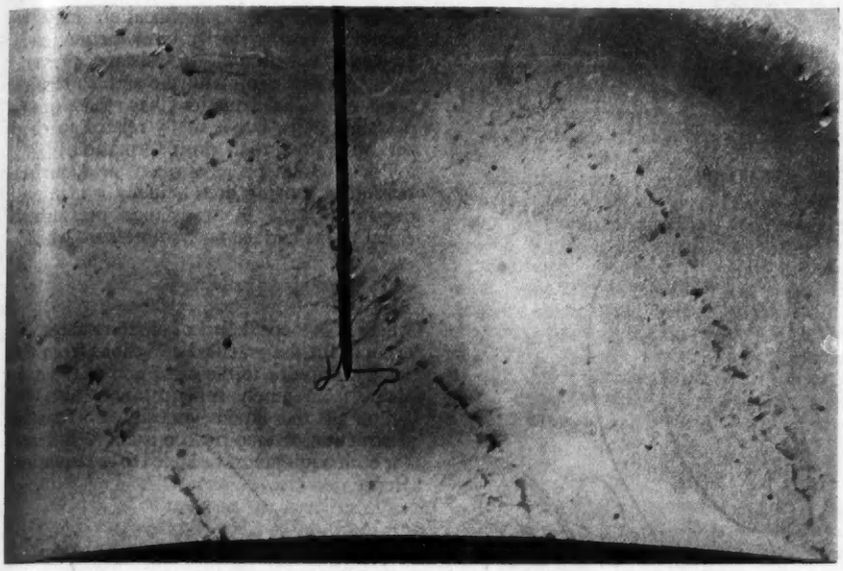

Fig. 8—Grooved disc with flat annulus rotating at 2500 r.p.m., with 50 g.p.h. water feed rate, magnification *circa* ×26

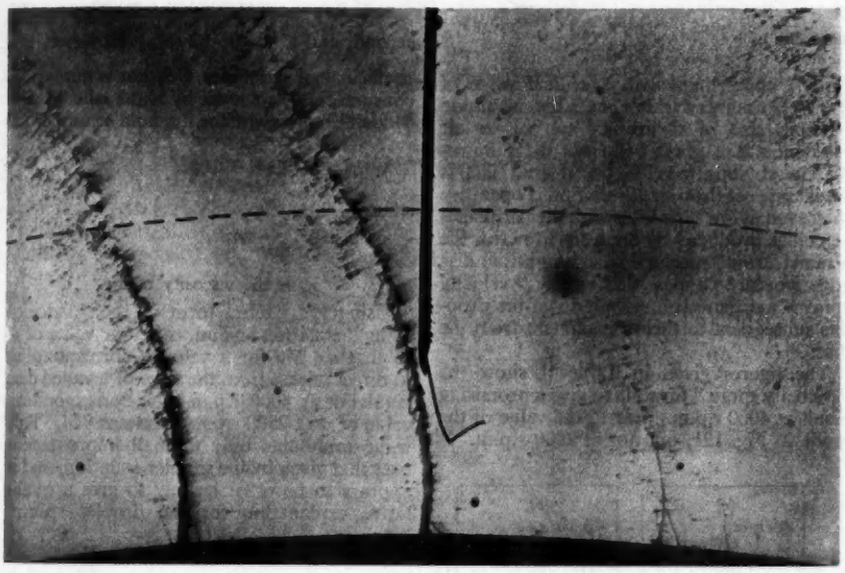

Fig. 9—Grooved disc rotating at 2500 r.p.m., with 50 g.p.h. water feed rate, magnification *circa* ×26

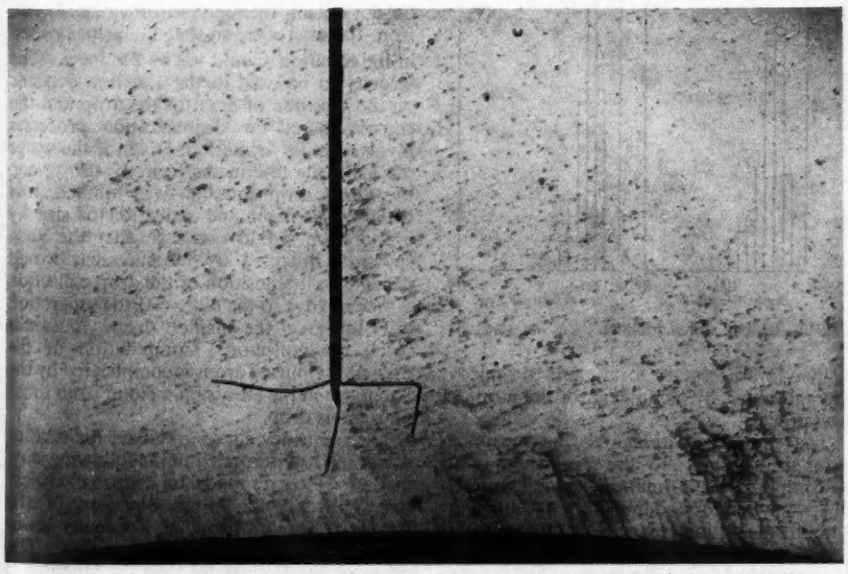

Fig. 10—Plane disc rotating at 2500 r.p.m., with 50 g.p.h. water feed rate, magnification *circa* ×26

pictures were obtained, each illustrating in varying degrees that some grooves were handling more water than others. The photographs were identified by lengths of wire bent into various shapes which can be seen in the illustrations. The wire thickness, which was 130 microns, also provided a rough check on the droplet sizing.

Fig. 9 shows a grooved disc of similar construction but without a flat annulus operating under the same conditions. The dotted line illustrates the relative position of the annulus edge in Fig. 8. In this photograph, the progressive destruction of the water jets issuing from the grooves is clearly shown and a comparison of the state of the jets at the dotted line with position at the disc edge in Fig. 8 illustrates the similarity between the droplet formation in the two discs. Even in the disc grooved to the outer edge some drops are produced by filaments from the edge and this is shown on the right-hand side of Fig. 9, near to the groove giving a very reduced water jet. At the different speeds and water rates which were investigated, as for the first disc, similar photographs were obtained.

Fig. 10 shows the formation of water droplets at the edge of a plane disc revolving at 2500 r.p.m. and fed with water at a rate of 50 gallons per hour. The secondary droplet formation from filaments at the disc edge, which occurred in the grooved discs, becomes the primary mechanism of formation in plane discs as illustrated. Similar photographs were obtained at 2500 r.p.m., 25 gallons per hour feed rate, and at 4000 r.p.m., 25 or 50 gallons per hour feed rate.

Vaned Discs

Plane discs produce a more homogeneous spray than grooved discs but a considerable proportion of the droplets produced by either grooved or plane discs have an initial velocity appreciably less than that of the disc periphery. Therefore, a vaned disc was designed in order to preserve the characteristic homogeneous spray formation by filaments typical of a plane disc, but to eliminate the reduction in the initial velocity of the drops due to slip by placing the flow surfaces and detachment edges for the water at right angles to the direction of motion. The disc illustrated in Fig. 11 had a diameter of 16in and consisted of twenty-four vanes each half an inch wide. The water was fed on to the leading face of each vane through a slit 0·010in wide, extending the whole width of the vane. The distribution ring, containing the feed slits, surrounded a central water reservoir fed by a pipe in the same way as the other discs.

An investigation of the droplet spectra produced by this disc was carried out for speeds of revolution of 2500 r.p.m. and 4000 r.p.m. The variation of the water feed rate between 25 gallons and 50 gallons per hour had no detectable effect on the size distribution at these speeds. Histograms of the droplet distribution are shown in Fig. 12.

With the vaned disc, no shallow craters in the oxide layer were observed, even when the air suction through the impactor was stopped. This seems to confirm that shallow craters are formed by low velocity droplets, making a bouncing contact, rather than by high velocity droplets.

Although the slip occurring on plane discs had been overcome, the vaned disc still did not conform to an equation of the Bär "direct drop" type, for the mean droplet diameters (37μ at 4000 r.p.m. and 48μ at 2500 r.p.m.) do not show a linear inverse relationship with the speed of revolution.

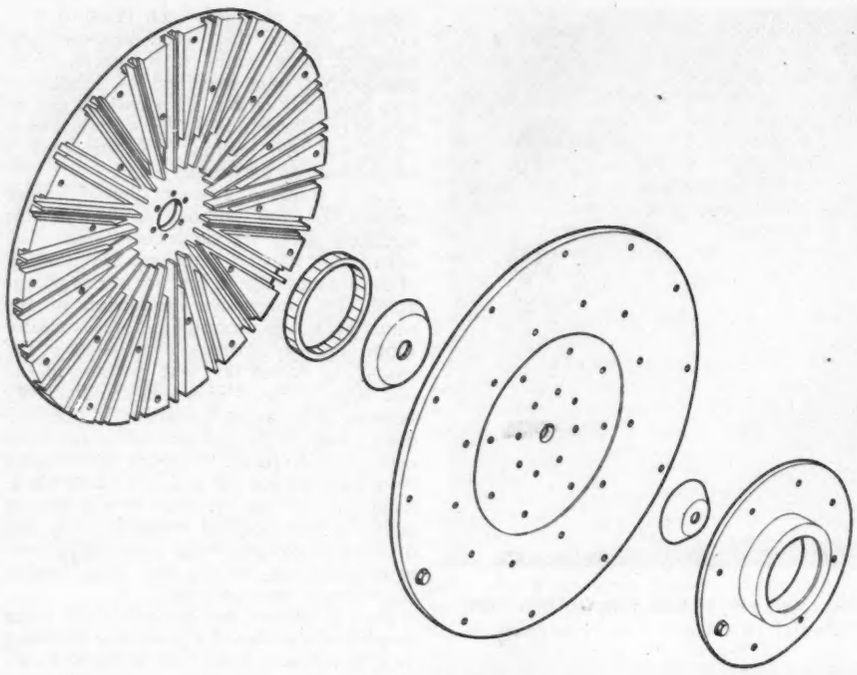

Fig. 11—Vaned disc

Unfortunately, the vaned and plane discs are not strictly comparable because the lengths of periphery at which droplet production occurs are different. In fact, due to simplifications to facilitate construction, the active peripheral length of the vaned disc was only one quarter of the plane disc. However, the independence of the droplet spectrum produced by the vaned disc on water feed rate variations from 25 gallons per hour to 50 gallons per hour indicates that the increase of the active length by a factor of 4 should not markedly change the droplet distribution.

Discussion

The droplet spectra obtained for a vaned disc, in which slip is obviated, show the inadequacy of the simple "direct drop" and "velocity spray" concepts in any analysis of the mechanism of atomisation. Probably due to the high flow rates and high peripheral speeds employed, the simple formulæ proposed by Bär do not apply, as shown by the comparison of the predicted and actual droplet diameters given in Table II.

Table II—*Droplet Diameters for a Vaned Disc of 8in Radius*

Rate of revolution of disc, r.p.m.	Maximum "direct drop" diameter (microns) $d=\frac{0\cdot525}{n}\left(\frac{\sigma}{\rho}\right)^{\frac{1}{2}}$	Maximum "velocity spray" drop diameter (microns) $d=\frac{0\cdot102\sigma}{n^2r^2\rho_a}$	Mean linear droplet diameter from vaned disc (microns)
2500	388	87	48
4000	149	34	37

The "direct drop" process involves the breakdown of the surface forces attaching the liquid to the disc edge by centrifugal force. When, however, water is fed to the disc at such a rate that this idealised mechanism is swamped then the water will be ejected from the disc edge in a non-homogeneous way. Once away from the influence of the disc edge, the water, whether in the form of a film, ligaments or drops, will be primarily influenced by impact and friction with the surrounding air. The "velocity spray" concept involves a critical value of the Weber number which limits the maximum possible size of a droplet subject to air resistance at a given velocity. It is immediately obvious from Table II that if this mechanism of drop size limitation is operative then even at low flow rates with the peripheral velocities produced by discs 8in in radius the "direct drop" mechanism acting at the disc edge would be superseded by the "velocity spray" mechanism breaking down the droplets subsequent to their detachment from the disc.

The figures given in Table II show the "velocity spray" formula to give a promising result at 4000 r.p.m., near to the value of the mode in Fig. 12*b*, but not at 2500 r.p.m. It

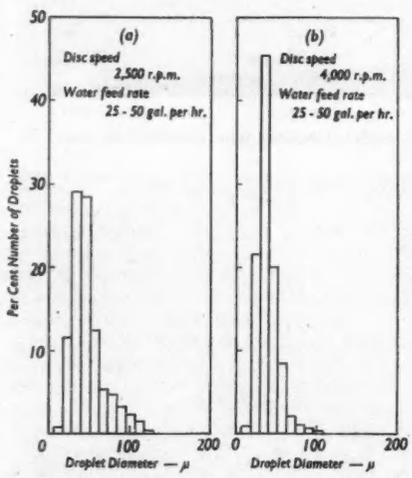

Fig. 12—Droplet size distribution curve for vaned disc

is therefore necessary to attempt to improve the agreement by an analysis of the atomisation process.

The simple equations relating maximum drop size to fluid and disc parameters apply to simple drop formation processes. But drops may be formed in many ways involving the disintegration of various intermediate forms, such as jets and films. If the problem is approached in a different way, first by considering the final drop product and, secondly, its creation, some simplification may be possible. The "velocity spray" equation is derived by equating the air resistance pressure on a spherical drop with the surface tension pressure. The equation has therefore a plausible basis, but is really related to drop survival rather than drop formation.

For a liquid sphere of diameter d, surface tension σ, moving at a velocity v in air of density ρ_a, the air resistance pressure is equal to the surface tension pressure when

$$C \cdot \tfrac{1}{2}\rho_a v^2 = \frac{4\sigma}{d}$$

where C is a coefficient of air resistance. To account for the practical deviations from this relationship due to the distortion of the drop shape from purely spherical and also the action of the liquid viscosity in resisting destruction, an empirical constant K (different for each liquid) must be added to the equation. Hence

$$d=\frac{8K\sigma}{C\rho_a v^2} \cdot \quad . \quad . \quad . \quad . \quad (4)$$

Equation (4) becomes identical with the Bär "velocity spray" equation (3) if v is made equal to $2\sqrt{2}\,\pi rn$, the initial velocity of a drop detaching itself from the edge of a disc of radius r revolving at n revolutions per second, and if $\frac{K}{C}=0\cdot102\,.\,\pi^2$. However, the coefficient of resistance C is not a numerical constant, but as shown by Dallavalle,[14] and Wadell[15] varies with the Reynold's number R_e.

$$C=\left(0\cdot63+\frac{4\cdot8}{\sqrt{R_e}}\right)^2$$

where

$$R_e=\frac{\rho_a v d}{\eta_a}$$

η_a is the viscosity of air.

Using the altered form of the "velocity spray" equation and adjusting the value of K so that $d=34\mu$ for a velocity corresponding to direct release from the edge of a vaned disc revolving at 4000 r.p.m., the corresponding value of d at 2500 r.p.m. becomes 82μ. This value represents only a small improvement over that given by the simpler equation, and it appears to be possible only to give a qualitative explanation for the droplet spectra obtained.

The most probable reasons for the failure of the more rigid "velocity spray" equation are connected with the value substituted for the drop velocity in the equation. The drops do not detach themselves in their final form from the disc edge, so that the velocity used in the equation should not be $2\sqrt{2}\,\pi rn$. The velocity to be used in the equation depends on the duration of flight of the drop and the complexity of the disintegration processes involved in its formation. Even if the water did leave the disc in the form of drops, e.g. the direct drop equation was fulfilled, loss of speed in flight and reduction of size by evaporation would occur so that the drop spectrum obtained by measurement would depend on the position of the drop collection device relative to the disc. If the separation were too great the smallest drops would not reach the collector. Computation of the drag on a cloud of drops is complicated by the difference in the effects on a cloud from those on a single drop.

The frequency curves obtained for various discs may be interpreted in the following way. The mode corresponds to drops of critical size, with respect to an equation of the "velocity spray" form, at a velocity lower than that at which they were created. The drops of larger diameter than the mode were formed at lower velocities and those of smaller

diameter than the mode are mainly the small satellites produced at various velocities during the creation of the others. The more complex the disintegration processes involved before the ultimate cloud of stable drops is produced, the greater the size range of drops and especially those of larger diameter than the mode. The spread of the smaller diameters could be expected to be fairly constant, depending more on the disintegration of smaller and less complex water formations. Concomitant with the broad size spectrum, resulting from complex disintegrations, would be a large velocity range at each drop size and considerable variation throughout the spectrum.

To obtain the most homogeneous spray the disintegration processes must be made as simple as possible. For example, the spectrum obtained for a vaned disc (Fig. 12), where the water is assumed to leave the disc in the form of thin filaments, like those shown in Fig. 10, is better than the spectrum for a grooved disc (Fig. 4), resulting from the break-up of jets of water. Probably an intermediate stage in the drop formation from the latter is the tearing of filaments from the jet surfaces, but this is obscured in Fig. 9 by the "comet tails" of the drops resulting from motion during the time of exposure of the photograph. If the disintegration is reduced to that of single drops after leaving the disc edge, the photographs of drop break-up obtained by Lane[16] indicate that perfect homogeneity is still unattainable; the largest drops, which are the main product of disintegration, are accompanied by a larger number of small satellites. This process is a possible explanation for the satellites obtained by Walton and Prewett[11] and for the increase of these satellites with increase of the feed rate of the liquid.

It is concluded that very homogeneous water sprays are only obtainable from spinning discs if the water feed rate to a disc, designed to prevent surface slip by vanes or other devices, is low enough to allow "direct drop" formation to occur at the disc periphery. If the simplest of the disintegration processes, that of a spherical drop, did not create a relatively large number of drops of different sizes, the two fluid nozzle atomiser would offer the most attractive source of large numbers of homogeneous drops. Whatever the complexity of the early disintegration processes, by the provision of a long convergent-divergent nose the resulting spray could be accelerated, with a relatively uniform velocity cross section, to allow "velocity spray" drop break-up to occur and be completed throughout the initial drop diameter spectrum before the aperture of the atomiser nose was reached.

Acknowledgments

The photographs shown in Figs. 1, 2 and 3 were taken by the B.I.S.R.A. Photographic Section, and those in Figs. 8, 9 and 10 by John Hadland.

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Friction Formulæ in Rivers and Channels

By J. R. D. FRANCIS, Assoc.I.C.E.

EMPIRICAL formulæ of the type $\bar{u}=Xm^a i^b$ are often used for calculations on the mean velocity $\bar{u}$, the hydraulic mean depth m, and the hydraulic gradient i in a river or canal. Colebrook (1939) showed that such formulæ can be regarded as approximations to the Prandtl's friction law for rough-walled pipes, assuming a reasonably small degree of experimental error; and Allen (1943) showed how the Prandtl law can be applied to open channels. It does not seem generally known, however, that there is some confirmatory evidence for the use of the more general Prandtl law for open channels.

Considering a very wide stream, in which m nearly equals the actual depth d, it may be shown that on the Prandtl-von-Karman mixing length hypothesis, the velocity distribution in a vertical plane is

$$u=5{\cdot}75\left(\frac{\tau}{\rho}\right)^{\frac{1}{2}}\log_{10}\frac{33y}{k}$$

where u is the velocity at a height y above the bed which is composed of roughness elements of an effective size k. These roughnesses cause a shear stress τ to be exerted on the bottom by the fluid, which is of density ρ. This equation is basically the same as was used for pipe flow. Now τ can be connected to the gradient by balancing the drop in pressure h on a length l of the channel against the shear force on the bottom and walls.

Thus,

$$\tau lP=\rho ghA$$

where P and A are respectively the wetted perimeter and cross sectional area of the flow.

That is

$$\frac{\tau}{\rho}=\frac{A}{P}g\frac{h}{l}\rho.$$

Since $h/l=i$ and $A/P=m=d$ for the wide channel,

$$\frac{\tau}{\rho}=(gdi)^{\frac{1}{2}}\log_{10}\frac{33y}{k}.$$

Now it is well-known by experience that a single observation of velocity at 0·6 of the depth from the surface (i.e. $y=0{\cdot}4d$ from the bed) gives the mean velocity $\bar{u}$.

So

$$\bar{u}=5{\cdot}75g^{\frac{1}{2}}(di)^{\frac{1}{2}}\log_{10}\frac{33\times 0{\cdot}4d}{k}$$

or in the usual feet-pound-seconds system of units,

$$\bar{u}=32{\cdot}6(di)^{\frac{1}{2}}\log_{10}\frac{13{\cdot}2d}{k}.$$

This formula may be used for friction calculations, though it involves knowing a constant k which corresponds to the constant X in the empirical type of formula. But now k is a measurable quantity and is the physical size of the roughness elements. It is not a number like, say, the Manning n, which though loosely connected to the roughness size is not in fact any direct measurement. Difficulties still arise, of course, when there is a mixture of roughness sizes present, exactly as in the case of the empirical equations. The superiority of the logarithmic equation lies in its immediate applicability if the depth of the channel is changed, while k remains constant. For example, it may be feasible to carry out friction tests in a channel at small depths when it is impracticable to carry them out at the greater working depths because it is impossible then to measure the discharge accurately. The tests at small d, and so small d/k, serve to find k; this value can then be used for calculating $\bar{u}$ at the greater depths to be used under operating conditions.

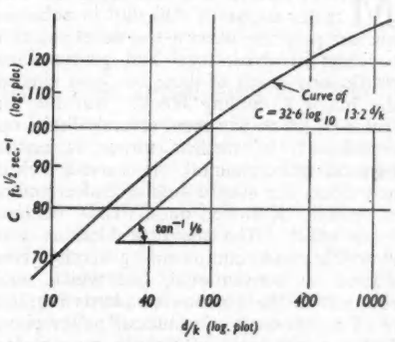
Comparison of the logarithmic formula may also be made with the simplest of empirical equations, that due to Chezy, namely,

$$\bar{u}=C(mi)^{\frac{1}{2}}=C(di)^{\frac{1}{2}} \text{ for the wide channel.}$$

The comparison shows that

$$C=32{\cdot}6\log_{10}\frac{13{\cdot}2d}{k}.$$

A curve may, therefore, be made of C against d/k, and this is shown in the figure, both axes being plotted logarithmically. At about



Constants in flow formulæ

$C=85\text{ft}^{\frac{1}{2}}$ sec.$^{-1}$ (i.e. $d/k=30$), the slope is seen to be $\tan^{-1}\frac{1}{6}$, so an approximation can be made at this one point only of

$$C=Y\left(\frac{d}{k}\right)^{\frac{1}{6}} \text{ where } Y \text{ is a constant.}$$

Substituting into Chezy's equation:

$$\bar{u}=Y\left(\frac{d}{k}\right)^{\frac{1}{6}}(di)^{\frac{1}{2}}$$

or

$$\bar{u}=Yk^{-\frac{1}{6}}d^{\frac{1}{3}}i^{\frac{1}{2}}.$$

This approximation has, therefore, the form of Manning's well-known empirical equation, $\bar{u}=Md^{\frac{2}{3}}i^{\frac{1}{2}}$, so that the Manning equation is but an approximation to the true state of affairs in a limited range of d/k.

Some confirmatory evidence for the reasoning above lies in the work of Strickler (1923), which appears to have been overlooked. Many years before the Prandtl-von-Karman velocity profile was evolved, Strickler had measured the Manning coefficient for a variety of surfaces and found quite empirically that $M\propto k^{-\frac{1}{6}}$, a conclusion which has just been reached above.

With channels having a greater roughness (so d/k smaller) the slope of the $C-d/k$

curve is greater and in the region of $C=60\text{ft}^{\frac{1}{2}}\text{ sec.}^{-1}$, an approximation is

$$C \propto \left(\frac{d}{k}\right)^{\frac{1}{6}}.$$

The corresponding approximate flow equation is

$$\bar{u} \propto d^{\frac{2}{3}} i^{\frac{1}{2}}$$

and this is the form of the empirical equation proposed by Lacey (1929). Examination of Lacey's data for irrigation canals shows that very probably the silt was being rippled by the flow over it. These ripples would have been the effective roughnesses in the channel and so might well be of the order of $d/k=10$ demanded by the graph in the figure on p. 519.

It will, therefore, be seen that any empirical equation of a power form is an approximation to the Prandtl curve, providing that the channel is hydrodynamically rough, as is usually the case. There seems, therefore little reason for attempting to produce more empirical equations, and it is better to quote roughnesses of surface as direct k values rather than the equivalent values of coefficients in more or less well-known empirical equations.

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Conventional Aspects of Nuclear Power

By REAR-ADMIRAL H. G. RICKOVER, U.S.N.

The address here reprinted was delivered last month before the Navy Guided Missile Preview Lunch in New York. Rear-Admiral Rickover is Chief of the Naval Reactors Branch, Division of Reactor Development, U.S. Atomic Energy Commission and Assistant Chief of the Bureau of Ships for Nuclear Propulsion. The point he makes is that, for use in nuclear power plants, plant other than the reactor itself has to be built to more exacting standards than have so far been demanded of engineering firms. He suggests, indeed, that it is the difficulty of attaining such exacting standards that is holding back the advance of nuclear engineering in the U.S.A. more than any lack of knowledge about the design of nuclear reactors themselves.

MANY factors have been suggested as the major source of difficulty in achieving nuclear power. Secrecy, the novel scientific concepts involved, legal and governmental restrictions—each of these has been cited as the major stumbling block. But the one factor which to-day most severely limits our exploitation of nuclear power is neither legal nor governmental. It is not a lack of new ideas, nor even a lack of understanding of recently developed ones. These do have some effect. The main problem is with materials and equipment generally considered as conventional, but which must conform to the exacting standards required of all components of a nuclear power plant. Just as the strength of a chain is no greater than that of its weakest link, so does the successful operation of a nuclear power plant depend on the reliability of all its parts—not alone the nuclear reactor, but also the heat exchangers, pumps, valves, &c. In fact, our experience with the four operating plants of the Naval Reactors Programme has shown that it is these components which have proved less reliable than the nuclear reactor itself. Also, the cost of these components has been high and their delivery time poor. They have thus been the cause of much of the high cost and long completion time of to-day's nuclear power plants. Here, I believe, is an aspect of nuclear power whose importance is little understood and which presents a challenge to industry.

Conventional Aspects of Nuclear Power

It is commonly believed that nuclear power development is primarily the province of the nuclear physicist. Nothing could be further from the truth. What actually faces us is the need to determine by calculation and by experiment how best to remove heat from a reactor, and then to design and build all of the components that make up the reactor system in such a way that they will operate efficiently and reliably under the rigorous conditions inherent in nuclear power generation. It has not been difficult to focus the necessary attention on the novel features of nuclear power, such as the nuclear reactor itself. Here new problems were expected ; they were easily recognised and are being reasonably well solved. But it has been very difficult to get sufficient effort directed toward the more conventional aspects of nuclear plants—the heat exchangers, the pumps, the valves, the instrumentation. Here normal engineering and manufacturing techniques have proved to be inadequate when applied to nuclear plants. To manufacture satisfactory nuclear plants requires that the whole plateau of engineering design, materials, inspection, and training be raised significantly above present levels. This is so because a failure which would be trivial in a non-nuclear application could have serious consequences where radioactivity is involved. It is also more difficult to maintain and repair equipment which is radioactive and welded hermetically tight.

Since the nuclear reactor is the most challenging and novel of the components that make up a nuclear power system, it attracts most of the technical attention. So it is not surprising to find that when industry speaks of getting into the nuclear power field it almost invariably refers to the design and development of reactors alone. To-day many companies interested in nuclear power dissipate the efforts of their technical manpower on academic reactor feasibility studies, but give little, if any, consideration to the overall reliability of the plant. The necessity for improving design and performance of the conventional type equipment, which transforms the heat generated by the nuclear reactor into useful power, is apparently either not understood or disregarded. As a result not enough effort is being expended to improve this equipment so that it can meet the exacting demands of nuclear power applications. The extent of this neglect cannot be measured in time and dollars alone ; it must also be measured in terms of what is to-day one of our scarcest and most priceless assets—trained technical manpower.

Let me give you some examples to demonstrate how to-day's normal engineering methods and manufacturing controls have proved inadequate for nuclear application and the steps which are being taken to remedy the situation. You will see from these examples that the development of naval nuclear propulsion is not a normal development which will follow inevitably from to-day's engineering and organisational facilities. On the contrary, it requires special effort both in engineering and in management. Three main factors are responsible for most of our difficulties in applying conventional type components to nuclear power plants. They are the need for shorter manufacturing time than is customary in conventional power plants ; the use of materials in shapes and under conditions different from those with which industry has had experience ; and the need for more rigorous criteria to evaluate the adequacy of materials and equipment.

There are good reasons for requiring shorter manufacturing times. The development of a nuclear reactor is a technically difficult and time-consuming undertaking. If the United States is to capitalise on any technological lead we may have in this field, our nuclear power plants must be built in a short time. For this reason our practice is to order the conventional type equipment for nuclear plants as soon as a preliminary design of the nuclear reactor has been firmed up. But our invariable experience has been that industry cannot deliver this equipment as quickly as it is needed, and this prevents us from fully exploiting our technological advantages. This is a sobering fact, especially since the welfare of our country in the future may well depend on the rapidity and the effectiveness with which we are able to exploit new concepts.

Secondly, nuclear power plants to-day require components which have different shapes and which are capable of operating under different conditions than those with which industry has had experience. We had expected that industry's technological know-how was sufficient to take care of these modest departures from conventional practice. We found this not to be so ; in fact, we found that industry frequently has inadequate understanding of the fundamentals involved even in straightforward applications. For this reason many of the problems that have arisen in our programme have had to be solved by empirical means. We have been forced to try many approaches, hoping that one would work. We cannot try all possibilities, and we cannot afford to continue trying several possibilities. We must first understand why something will work or will not work. Until the fundamental processes involved are understood additional large-scale use of technical manpower and money will be required to solve each new, even slightly different, problem as it arises. The empirical methods we are using are rapidly becoming unsuitable for solving these problems. This empirical approach is enormously wasteful of money and trained technical manpower ; it also results in unexpected and unexplainable flaws and failures. These continue to plague us and cause considerable delay.

Finally, the necessity for use of more rigorous inspection criteria arises from the emphasis we necessarily place on reliability. Failure of a component in a nuclear power plant has far greater significance to plant safety and operation than a similar failure in a conventional plant. The reason, as I

have mentioned, is the radioactivity hazard and the resultant difficulty of access for maintenance and repair. While this can be minimised by proper choice of reactor coolants serious problems nevertheless remain, which have not been sufficiently appreciated by many who are working on reactor plant design and manufacture.

Thus it is clear that conventional type components when used in nuclear power plants must meet far more exacting standards and must demand a higher order of engineering than similar components used in normal industrial applications. This is a challenge to industry which is not yet thoroughly understood or accepted.

Some Problems

To illustrate the problems which arise from these special requirements of nuclear power plants I will give you a few examples.

Lack of Fundamental Understanding.—Our present knowledge of stainless steel is far from satisfactory. We have had to devote excessive attention to its fabrication and weldability to assure that the end product will be satisfactory. This is a field where fundamental knowledge leading to more effective methods and techniques is urgently needed.

Many of our steam generators use stainless steel tubes. Despite every design and operating precaution taken by us, we have experienced leaks in some of our steam generators. One corrective measure is to stress-relieve the stainless steel tubing to minimise corrosion. The manufacturers of this equipment have had years of experience in fabricating tubes. Yet when they were confronted with the requirement to stress relieve stainless steel tubes, without resultant surface contamination or distortion, they needed no less than five months to develop their processes. These five months were not anticipated by us and caused a corresponding delay in the completion of the steam generators for one of our newer ships. But even after this delay of five months and the expenditure of close to a million dollars we still do not have a good understanding of this technical problem. Here, as in many other cases, we had to spend considerable time and money on a " brute force " approach because there was no hope of obtaining an understanding of the fundamentals involved in a reasonable length of time.

Obtaining sound carbon steel forgings and castings has continuously plagued us and is a major problem. Experiences with defective forgings and castings have forced us to order twice as many as are actually needed in order to ensure a sufficient number of satisfactory ones. For example, one of our contractors needed about fifty large forgings. Yet no less than one hundred had to be made in order to supply these fifty ; the other fifty were so poor they had to be scrapped. I estimate that during the next five years the Naval Reactors Programme alone will require about six hundred large forgings. If the present rejection rate continues an additional six hundred forgings will have to be made and scrapped, at a waste of millions of dollars.

The same is true of large stainless steel castings. Many of these have had gross defects. We have had to become reconciled to the fact that here again extra units must be made to be certain of obtaining a sufficient number of good ones. We still have not learned why these difficulties arise and how sound parts can be assured. I estimate that 2750 castings weighing about 7,500,000 lb will be required during the next five years in the naval programme. If the present rejection rate continues, about 4100 castings will have to be made in order to meet this requirement. The cost of the additional castings which will have to be scrapped is estimated as several million dollars. These rejection rates for forgings and castings certainly do not speak well for our fundamental understanding of materials and their fabrication.

Management.—My second point is the need for an entirely new quality level of management to insure a satisfactory product. It is even more important, but more difficult to illustrate in a brief talk. We have found that before a company can produce heat exchangers, valves, pumps, instruments, or other components suitable for a nuclear power plant, a complete revision of its normal organisational procedures is necessary. A full-time project manager responsible directly to top management must be placed in charge of the nuclear products. He must establish new levels of engineering and scientific competence. This generally requires that personnel be given special education and training —academic evening courses at nearby schools or universities, and practical courses at the plant itself. Management will have to pay more attention to the training of personnel in administrative methods and in purchasing and expediting. New tools and procedures for inspection must be developed and put into use. Facilities for testing raw materials and the final product must be designed and installed. Often these are very expensive. In short, an entirely new level of technical and administrative competence must be built up for even the so-called conventional-type equipment.

For example, in one experimental programme nine small industrial-type pumps were ordered, one at a time, over a period of a year by our laboratories. These were a standard commercial product, ordered from several companies, out of their catalogues of stocked items. They were to be used for laboratory tests of a completely non-nuclear nature. Yet each of the nine pumps had some serious defect upon delivery : poor castings which allowed gross leakage, misalignment which prevented operation, incorrect material used. Such defects can easily be corrected in most applications ; they are only a nuisance. In a nuclear power plant, however, where radioactivity is involved, such defects are intolerable. Contrast this situation with the performance of the special canned-rotor pumps we had to develop for nuclear application. These developmental pumps, welded into place, require no lubrication and have run for years without inspection. They have received no attention and show no signs for needing any. Three industrial concerns have now been trained to make these pumps. Because of their reliability they are now also finding use in non-nuclear applications.

The difficulties I have discussed represent a very small number of those we have so far encountered ; as our programme expands the number of problems increases. They are but an indication of the difficulties with so-called conventional-type equipment which must be faced and solved before a nuclear power industry can become a reality.

Lessons

Two lessons stand out from what I have said :

Too much dependence is currently being placed on routine design and production methods. Practical nuclear power cannot be achieved by routine methods. The performance and safety standards of nuclear plants pose problems which require technology far in advance of that now being used. We have found from numerous and repeated experiences that the only way these problems can be solved is by special and persistent attention by management. One or more individuals, competent in technology as well as in administration, must be appointed on a full-time basis in each organisation to follow the nuclear work and to report directly to management. Otherwise, management will not really know the status of these development items and will not be able to make certain that satisfactory results will be achieved on time.

Companies should determine where their background and talent can best meet the needs of nuclear power. For most companies this is not in the design of the reactor itself ; rather it lies in the development or perfection of reliable, higher performance materials and components. Right now nuclear power requires that practically everything be designed by scientific methods.

To-day there exists both a great opportunity and a great challenge in the nuclear power field. Those who realise that a major function of management is to plan for the future, and who are willing to undertake difficult work, including achievement of better understanding of fundamentals, will be the ones who remain in this field and benefit from it because they will be solving tomorrow's problems to-day. If this challenge is accepted and successfully met, the entire level of technology, management and productive skill in the United States will be raised. This is of vital interest to our country if we are to maintain the technological supremacy which is fundamental to our survival.

Main Line Diesel-Electric Trains

It has been announced that a contract for the design and construction of five high-speed diesel-electric trains for main line express service has been placed with the Metropolitan-Cammell Carriage and Wagon Company, Ltd., Saltley, Birmingham, by the British Transport Commission. These all-Pullman trains are planned to go into service in 1958 and will run between Manchester and London (St. Pancras) on the London Midland Region, between Bristol and London (Paddington), and between Wolverhampton, Birmingham and London (Paddington) on the Western Region. Two of the trains will be six-car sets for first-class passengers only for the Manchester-London service, whilst the remaining three trains will be of eight cars for the Western Region and they will have accommodation for both first and second-class passengers. All of the trains will be air conditioned and provided with heat and sound insulation. The power equipment for the new trains is being supplied by The General Electric Company, Ltd., and there will be two power cars on each train. In each power car there will be a machinery compartment housing an N.B.L./M.A.N. 1000 h.p. pressure-charged V-twelve-cylinder engine, directly coupled to a G.E.C. single bearing main generator with a belt-driven auxiliary generator. Eight self-ventilated traction motors distributed through the train will be fully spring-borne in the bogies and geared to the axles through Brown-Boveri spring drives. The control system will comprise a combination of main generator field control and engine speed variation, with automatic torque control through an oil servo-regulator. A range of several engine speeds will be provided by three air-operated pistons acting on the engine governor through a system of interconnected levers.

Gear Failures of Ball, Tube and Rod Mills

By H. E. ROSE, D.Sc.(Eng.), Ph.D., M.I.Mech.E., M.I.C.E.*

In this article the breakdown of the gearing of ball, tube and rod mills is discussed, and it is suggested that the failures are due to fatigue arising from the surging of the charge in the mill ; even though the surging is insufficient to be manifest by reason of noise or current surges sufficient to trip the circuit breakers protecting the driving motor. A criterion for surging in such mills is given and it is suggested that if the mills were operated within the limits set down, the frequency of such failures would be reduced and more economical designs might be adopted.

THE ball, tube and rod mill are a family of machines of considerable industrial importance and the larger members of the family, tube mills, require an appreciable power, perhaps up to 2000 h.p., to drive them. The design of the driving gears for such machines is complicated by the fact that gears, which by all normal standards of design are of adequate proportions, are, in some cases, subject to inexplicable failures after a comparatively short running life. These failures present considerable problems in their analysis in that gears which are constructed to specifications which are satisfactory in other onerous duties, such as the drives of rolling mills, sometimes fail. Furthermore, gearing finished to a degree of accuracy comparable with that demanded for turbine reduction gearing appears to be no more satisfactory than that with a less precise finish ; on the other hand, gears finished to a quite low standard of precision are often quite satisfactory. The problem is still further confused by the observation that it sometimes happens that, of two mills of identical design and grinding apparently similar materials, the gearing of one mill gives almost unlimited service whilst that of the other fails after a comparatively short time. Thus, it appears that the factors which control the failure of the gearing are dependent upon differences in the design of the mills, or in the nature of the material being ground, which are so small as normally to escape observation.

The kinds of failure encountered in these mills are those encountered in any other gear failure, such as, by scuffing of the working faces of the teeth, breakage at the root of the teeth, radial cracking of the wheel rim, slipping of the rim on the hub (when shrunk on). The general nature of the failures suggests that the basic cause is fatigue of the metal, arising from rapid repeated fluctuations in the driving torque, and it is shown in this article that these fluctuations can well arise from oscillations of the charge within the mill.

The present analysis suggests that it is probable that the gearing of most mills in successful operation is excessively generously proportioned, since by this means failures are minimised, and so it is probable that, provided the magnitude of the torque fluctuations could be consistently limited to small values, more economical designs could be adopted.

Surging of the Charge in a Mill

When the mill shell is running at a constant speed ω, the mill charge, consisting of powder together with rods or balls, as the case may be, takes a position, as shown in Fig. 1, in which the centre of gravity is displaced from the vertical by an amount given by the angle θ. If the motion were absolutely steady the angle θ would be constant and the balls, or rods, would roll down the surface of the charge or, if the speed of rotation were high enough, would be projected along on approximately parabolic path within the mill shell. The important point is, however, that the angle θ would remain constant and the torque to maintain the mill shell in steady motion would also be constant.

Such an ideal state of affairs can scarcely be expected to exist in any real mill and a temporary increase in the coefficient of friction between the charge and the shell would cause the centre of gravity of the charge to be carried beyond the equilibrium position. With increasing displacement of the centre of gravity the restoring torque increases until the frictional forces at the interface between the charge and the mill shell, corresponding to this increased coefficient of friction, is exceeded, whereupon the charge slides down the shell with increasing velocity and the centre of gravity is carried beyond the equilibrium position, in the negative direction. After coming to rest the charge " locks on " to the mill shell, static friction again becomes operative and, once more, the charge is carried beyond the equilibrium position. Thus, if conditions are correct, the cycle may be repeated indefinitely. It will be seen that, in general, one of the necessary conditions for the oscillation of the charge is that the coefficient of static friction shall be greater than the coefficient of dynamic friction, and this condition is generally fulfilled by most practical materials. Thus, the mill charge may oscillate like a pendulum within the mill shell

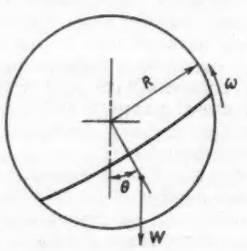

Fig. 1

and these oscillations would be accompanied by a fluctuation in the torque necessary to maintain the mill shell in steady motion.

If a mill of about 8ft diameter, with about 40 per cent of the cross-sectional area occupied by balls and charge, is considered, it is clear that the distance from the axis of rotation to the centre of gravity of the charge will be about 3ft and so, treating the charge as a simple pendulum, an oscillation having a frequency of about 1 c/s would be expected and surging of this order of frequency is encountered in mills of the size quoted. Readings of an ammeter placed in the motor circuit indicate that the peak current drawn by a mill during surging often exceeds two and a half times the mean value, and this is a rough indication of the possible magnitude of the fluctuations of torque.

These figures for both magnitude and period of the fluctuations of torque have been roughly confirmed by a theoretical analysis, carried out by the present writer, Rose,[1] in which the motion of the charge in a mill of 8ft diameter was investigated ; use being made of the method of topology for the analysis of the non-linear differential equation involved. The result of this investigation is shown in Fig. 2, and it is

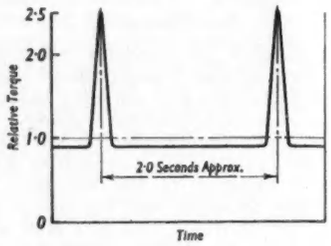

Fig. 2

seen that the maximum torque is about two and a half times the mean torque and the period of the oscillation is of the order of two seconds.

The motion of the charge is complicated by the fact that the charge is not a solid body but is composed of a large number of separate particles. In this case, as long as the charge is moving with the mill shell there is a considerable centripetal force acting on each ball and there is also considerable contact pressure between the balls at the " toe " of the charge and the mill shell. As soon, however, as the charge slips at the shell and comes to rest, the " toe " of the charge collapses and this, to some extent, reduces the moment due to the weight of the charge. The charge might then tend to climb again before the main sliding motion becomes effective. In any case this collapse of the " toe " of the charge would give rise to small fluctuations of torque, superimposed on the main fluctuations and, from the well-known principles of harmonic analysis, it would be expected that such fluctuations could be analysed into a combination of a large number of component vibrations of different frequencies. There is some evidence that the frequency spectrum for a tumbling mill does, in fact, contain a wide range of harmonics and so this idea is, to some extent, confirmed.

The existence of surging on a large scale is shown by the emission by the mill of considerable noise and, in extreme cases, by the tripping of the circuit breakers which protect the driving motor. Clearly such gross surging cannot be tolerated and, if it should occur in practice, the conditions in the mill are altered until the major manifestations of the phenomenon are eliminated. It is unlikely, however, that the phenomenon of surging is such that it is either markedly existent or completely non-existent and, in fact, it is probable that there exists fluctuations in the driving torque of many mills which are running under conditions such that the gross signs of surging are absent.

The present writer, with a co-worker, (Rose and Blunt,[2]) have investigated the conditions for surging in ball mills, by the use of small-scale models, and have evolved a criterion for the existence, or non-existence, of surging. This criterion states that in order that surging shall not occur it is

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necessary that the dimensionless groups $(J\times\mu)$ and (D/d) shall be such that the operation point for the mill shall be above the line of Fig. 3. Here J is the fraction of the mill volume filled with balls plus the space between the balls, μ is the mean of the coefficients of static and dynamic friction, D is the inside diameter of the mill and d is the mean diameter of the balls in the ball charge. The value of μ may be simply determined by placing a mass of the balls and powder involved in a bottomless box, on a steel plate, and noting, by means of a spring balance, the tractive force necessary to start the box, and to maintain it in motion once started. The reason for the entrance into the problem of the groups $(J\times\mu)$ and (D/d) is fully discussed in the paper cited. The question has been discussed indirectly, in a further paper by Rose and Evans,[3] and here also the validity of use of these groups is justified.

Thus, if by a change in the coefficient of friction of the material of the charge, the operating point is brought below the line on Fig. 3, surging can occur. With the present

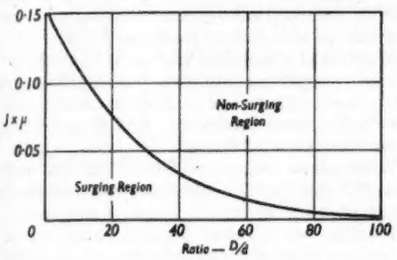

Fig. 3

state of knowledge of the subject it is impossible to state that surging will occur when the operating point falls below the line, but that it can occur has been clearly demonstrated. The existence of this possibility is, however, sufficient for the present purpose. That this criterion is complied with in the operation of large industrial mills is demonstrated by Fig. 4, in which the operating points of a number of industrial mills are plotted; these points being calculated from the published data of Taggart[4] and data furnished by Acheson Colloids, Ltd.[5]

As already suggested, it is unlikely that surging is a phenomenon such that the fluctuations of torque are either of considerable magnitude or are completely eliminated. It is far more likely that when the operating point is slightly below the boundary line there is a small, and in practice indetectable, fluctuation in the torque whilst increasing distances between the operating point and the line correspond to increasing fluctuations in the torque. Conversely, the further the operating point is above the line the more stable is the motion of the charge and the less the possibility of some irregularity in the charge giving rise to a surge. Furthermore, when the point is well above the boundary line, any surge which might be initiated by some irregularity in the charge would be quickly damped out. On the basis of this idea it would appear that, on a graph such as Fig. 3, it should be possible to plot a series of lines such that when the operating point is above the line the fluctuation in torque* is less than a certain fraction of the mean torque, and when it is below the line the fluctuation is greater than this figure; a series of such tentative curves is shown in Fig. 5. (These curves have not been

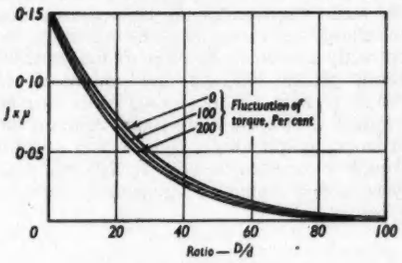

Fig. 5

determined experimentally and so should be regarded as suggestive only.)

Turning now to the behaviour of a steel under fluctuating stress, it is well known that the fatigue characteristics may be represented by a diagram of the form shown in Fig. 6. For the material to have an indefinite

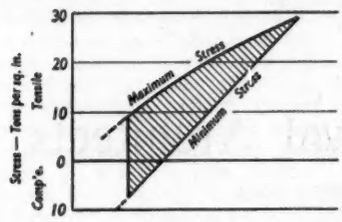

Fig. 6

life it is necessary that the fluctuation of stress should be related to the mean stress in such a way that the operating conditions for the material always fall within the shaded area. Thus, for example, if unlimited life is to be attained when the mean stress is 20 tons per square inch, then the fluctuation of stress

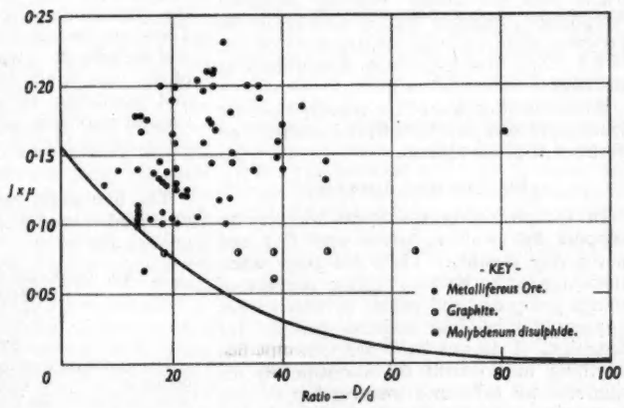

Fig. 4

must not exceed about ±3 tons per square inch. If, however, the mean stress is 10 tons per square inch, the allowable fluctuation for indefinite life is about ±6 tons per square inch. If these limits of fluctuation are exceeded then the material will fail for some limited number of applications of stress, the number of applications before failure decreasing rapidly as the limits are more widely exceeded.

*Percentage fluctation of torque is $\frac{\text{Maximum torque—Mean torque}}{\text{Mean torque.}}$

Let these ideas now be applied to the case of a mill, and in the first place let it be assumed that the mill has a 25 per cent $(J=0{\cdot}25)$ filling, that the material being ground is such as to give a mean coefficient of friction μ of 0·32, that the mill diameter is 8ft and the mean diameter of the balls in the charge is 5in. In this case $J\times\mu=0{\cdot}08$ and $D/d=19{\cdot}2$ and from Fig. 3 it is seen that the operating point is fairly well inside the "non-surging" region. Thus, negligible fluctuations in the torque would be expected and since the power to drive the mill may be calculated, by use of numerous formulæ, e.g. those of Carey and Stairmand,[6] Hancock,[7] Bond,[8] Davis,[9] or Rose and Evans,[10] to within, say, 10 per cent, no trouble would be experienced.

If now an apparently small change is made—that is, the mill is run as a "wet" mill instead of as a dry mill—then the coefficient of friction of the charge might be reduced to, say, 80 per cent of the previous value and so $J\times\mu=0{\cdot}64$ and the operating point then falls within the "surging" zone. Furthermore, reference to Fig. 5 shows, if the curves are assumed to be approximately correct, that the operating point corresponds to an increase in torque of 150 per cent above the mean value. Supposing, however, that the gearing has been designed such that, for the steady driving conditions, the working stress is about 10 tons per inch, then the maximum torque attained would correspond to 25 tons per square inch, which falls outside the shaded area on Fig. 6, and so fatigue failure would be expected. Thus, the small change from dry to wet milling would appear to be sufficient to lead to fatigue failures in the gearing of a mill which would, for dry milling, have an almost indefinite life. Furthermore, if in order to improve the grinding of a hard material the mean diameter of the balls in the *dry* mill is increased from 5in to 6in, then $D/d=16$ and the operating point then corresponds to 100 per cent increase in the torque maximum. Thus, either of these small changes could be sufficient to bring about fatigue failure.

The foregoing treatment suggests the manner in which the curves of Figs. 5 and 6 may be used to predict the possibility of gear failure and it is believed that by their application many of the failures now encountered in practice could be eliminated. The maximum stress attained will to some extent be modified by the design of the mill and of the driving motor. Thus, if the motor is of such a design that it loses speed with increasing torque, the mill shell will decelerate under conditions of maximum torque and the gearing will be relieved of the heaviest stresses. Also a mill with a relatively heavy shell would give rise to less stress fluctuations in the gearing, since the shell will act as a "flywheel" and tend to "smooth out" the torque fluctuations.

It is now interesting to attempt to find some confirmation that the breakdowns are probably fatigue failures arising from the cause suggested.

It appears that gear failures either occur after some few thousand hours of running or that the life is completely satisfactory, although there are many deviations from this general statement. Assuming now that the mill shell runs at 20 r.p.m., which is reasonable for a large mill, and let the last stage of reduction have a ratio of 5 to 1. If, now, the surge has a period of two seconds, as has already been shown to be of the correct order, then it follows that in the period of one surge (two seconds) the pinion will make 3½ revolutions and so a given tooth will

encounter a stress peak once in ten revolutions. Since, however, the pinion runs at 100 r.p.m. the number of stress maxima encountered in 10,000 hours will be $60 \times 10{,}000 \times 100/10 = 6{,}000{,}000$. Now it is known that at least for fluctuations of moderate magnitude the number of reversals of stress before failure is of the order of 1,000,000 to 10,000,000 and, having regard for the roughness of the present calculations, it is hard to escape the conclusion that many gear failures in tumbling mills are fatigue failures having the origin suggested.

It will be noticed that a slipping between the charge and the mill shell is postulated and it is clear that such slipping could be suppressed by the provision of very heavy lifter bars in the mill shell. It does appear, however, that the normal types of mill liners, such as wave or "ship-lap" liners, offer insufficient keying of the charge to the shell to eliminate surging from a mill which is liable to surge, and it is probable that, with such a mill, the diameter of ball or the size of the charge of the mill, or both, should be altered to bring the operating point within the non-surging zone, rather than the provision of exceptionally heavy lifter bars, which would be subject to excessive wear and so to high replacement costs.

In this article it is suggested that the inexplicable failures which occur in the gearing of tumbling mills can be attributed to fatigue arising from surging of the charge in the mill; torque fluctuations being present even though the gross manifestations of surging, such as noise and the tripping of the circuit breakers protecting the driving motor are not present.

A criterion for the existence, or otherwise, of surging is given and it is suggested that if the mean diameter of the balls constituting the charge and the value of the mill filling are correctly chosen in relation to the material being ground and to the conditions of grinding, then the operating point can be brought within the non-surging zone on the criterion graph, Fig. 3, in which case it would be expected that the incidence of such gear failures would be significantly reduced.

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Institution of Naval Architects

ANNUAL SPRING MEETING

No. I

ON Tuesday morning, March 26, the annual general meeting of the Institution of Naval Architects was held in Weir Lecture Hall at 10, Upper Belgrave Street, London, S.W.1. The annual report, read by the secretary, recorded that Viscount Runciman of Doxford had consented to continue in office as president for the period 1957 to 1959 and that the Council had elected Vice-Admiral Sir Cecil P. Talbot, K.C.B., K.B.E., as an honorary vice-president. The total of all classes of membership, it was noted, had increased by 91 to 3957.

The William Froude Gold Medal was awarded to Dr. R. W. L. Gawn, C.B.E., D.Sc., for his work in hydrodynamics, and the Institution's premiums were awarded to Mr. J. W. Ramsay, B.Sc., for his paper "Aspects of Ship Vibration Induced by Twin Propellers," and to Mr. A. A. Wells, B.Sc., Ph.D., for his paper "The Brittle Fracture Strength of Welded Steel Plates." Mr. K. K. Lo, of the Royal Technical College, Glasgow, and Mr. R. W. Bass, of the Portsmouth College of Technology, received Duke of Northumberland prizes, and the report stated that 141 National Certificates in Naval Architecture at ordinary level were awarded, while the total at higher level amounted to seventy-nine. Both totals exceeded the number of certificates gained in the previous year. The prize of the City and Guilds of London Institute was awarded to Mr. L. Church, and the second prize to Mr. C. M. Jones, both of whom are students of Southampton Technical College.

The activities of the Southern Joint Branch are recorded in the report and also those of the Australian Branch, which has a membership of 153. Particulars of the increase in value of a number of scholarships are included, together with a list of scholarship awards made in 1956 and of scholarships offered for competition in 1957. Brief summaries are given of the work forming the programmes of the British Shipbuilding Research Association, the Ship Division of the National Physical Laboratory, Pametrada, and the British Welding Research Association, together with a note upon the progress made in the construction of the N.P.L. Ship Hydrodynamics Laboratory at Feltham.

After the adoption of the report, Viscount Runciman gave his presidential address, an abstract of which follows.

PRESIDENTIAL ADDRESS

In the profession which we are here to support things move never very fast and never very steadily. There are years when there appear to be an immense number of things going on, and others in which there appears to be less activity—periods for digestion. I do not know whether this has anything to do with the variation in the numbers we take into membership of this Institution each year, the average over the last five years being 89 and the variation between 58 and 138. It is satisfactory that we do get this intake, which is perhaps evidence of the quality we require in our members, and shows no signs of falling off; and it is an intake, moreover, which is not confined to this country, but is widely spread throughout the world.

A matter which may in the course of time produce the greatest effect stems from the symposium on education held jointly with the Institute of Marine Engineers. It may well be that out of the discussions that ensued there may emerge certain basic points of view and suggestions for improvements which will perhaps bring about a gradually widening interest by the public at large in naval architecture and marine engineering, the problems they present and the importance of them to this country. It will be a long process and it will be necessary to bring into consultation an ever widening range of people, and I hope it will be pursued with all the vigour it deserves and that we may look forward to a fruitful outcome.

You will be aware of the arrangements for the summer meeting in Bristol in July. It is also gratifying to know that we have received an invitation from the Association Technique Maritime et Aeronautique in France to hold a joint summer meeting with them, which will probably take place in Paris in the early days of July next year.

If one surveys the general state of naval architecture at this time, it seems to me that the most exciting things in the immediate offing are in the field of propulsion, the field of the marine engineer, and it will be for us to see what he has to offer and what we can contribute simultaneously with him. I am inclined to think that we are perhaps in a waiting period. It is bewildering if you are a shipowner considering the ordering of a ship for the rather distant future and think of the propulsion you will employ. Are you to look ahead to gas turbines, are you to follow up the American full-scale experiments in controllable pitch propellers, or are you to go into the noisier fields of free piston engines? What about supercharged diesels and what is the limit of horsepower you can really expect to transmit through a crankshaft? Finally, what about nuclear energy itself? Are we to go on thinking of nuclear power solely as a source of heat, or are we on the threshold of new discoveries which will make nuclear energy a direct source of power itself?

Problems are always changing. If you look at naval construction for this year you will find that something like fifty small ships have been completed, and when you consider the problems which face the Navy in cramming into those very small hulls, under reasonable living conditions, the crews necessary to fight those ships you will appreciate the importance of research in habitability. There are also the problems of higher speed and planing, &c., which emphasise the value of the work which Dr. Gawn has been doing and continues to do at Haslar. Metallurgical problems are occupying increasing attention at Dunfermline.

The first paper presented at the meeting was read immediately after the presidential address and was:

OCEAN IRON ORE CARRIERS—DESIGN CONSIDERATIONS

By JAMES LENAGHAN

SYNOPSIS

This paper deals with a number of points in the design of iron ore carriers. At present there are about fifty-seven ore carriers under construction or on order for United Kingdom account, and as the demand for imported ores increases so will the demand for bulk carriers specially designed for the ore trade. Ore carriers account for 6 per cent of the total tonnage under construction in this country. The most serious limiting factor in design of these ships is draught, and tables give berthing restrictions at both home and overseas ports. Length of ore compartments is dealt with and also ballasting arrangements and unloading arrangements, while the position of the navigating bridge is examined.

DISCUSSION

Mr. J. Hodgson: These ships have to carry continuously the most unkindly type of cargo, very often loaded and discharged by most barbarous methods, and therefore they have to be stronger and more robust than the

normal dry cargo ship, and generally are equivalent in strength to tankers. The bad effect of restricted draught is quite evident from the comparison between the two ships in Table V, also the benefit of having more rational depth in the ship, from both the construction and the stability points of view. Greater depth also keeps down the thickness of the deck and bottom plating; this is important in welded ships on account of the possible adverse effect of increased thickness on the notch ductility of the steel.

It should be made clear that the paragraph in Lloyd's Rules, to which the author refers (page 6) requires the longitudinal bulkheads to be a minimum distance of 0·2B from the ship's sides only when a draught in excess of the ordinary cargo ship draught is desired, i.e. when the freeboard is assigned under the special regulations which permit deeper loading in ships having construction similar to that of a tanker. Watertight subdivision is one of the supplementary conditions of freeboard assignment for this deeper loading, and is therefore prescribed for in Lloyd's Rules. This condition also governs the spacing of the bulkheads in the wing tanks.

Many modern ore carriers operate on the ordinary cargo draught and are not subject to the subdivision restriction; there is then more latitude for positioning the longitudinal bulkheads. Many have greater hold capacities for lighter ores and other similar bulk cargoes, and it is then usual to depart from the vertical sided hold and to crank the longitudinal bulkheads to facilitate trimming and discharge. This has the advantage of avoiding abnormal increase in width of hatchways, which in turn has the structural advantage of minimising the thickness of plating alongside the hatchways.

It is agreed that the fewer divisions the better, particularly in the specialised iron ore carriers. Very long centre holds can, however, be obtained without penalty, even under the deeper loading regulations, provided it can be shown that the flooding of the hold would not endanger the ship.

Structurally, a minimum number of complete transverse diaphragms is desirable in these large single-deck ships. I do not think that any factual notation in the Appendix of Lloyd's Register Book regarding the number of complete bulkheads fitted should be regarded as a penalty. I am interested to know how Mr. Lenaghan has arrived at the figure of 0·225L for suitable hold length.

I understand that many officers, at first sceptical about manœuvring these big ships from aft, find after experience that there are no difficulties, except that perhaps the midship position has the advantage of being away from the noise of the engine, and the men on the bridge can hear fog signals better than they can when stationed aft.

An important anomaly exists in the register tonnage of this type of ship, when measured under the regulations of different countries. This arises from the different methods of treating bona fide water ballast spaces, which are of very large volume in the one-purpose ore carrier. When the tonnage is measured in countries which have adopted the International Tonnage Regulations the amount of water ballast space which can be exempted is limited to 9·5 per cent of the gross tonnage in a ship of about 10,000 tons gross and about 7·5 per cent in a ship of 15,000 tons gross or over. In some countries not acceding to the Tonnage Convention all the water ballast tanks are exempted from inclusion in the gross tonnage, without limitation. Thus there is a tremendous difference between the tonnages of similar ships carrying the same deadweight when measured under the two systems, and in a ship of about 24,000 tons deadweight the gross tonnage of the ship measured under the limiting regulations might be more than double that of the ship not subject to the limitation.

Professor E. V. Telfer: I think that the question of depth and draught should be emphasised because it is surprisingly little known how draught varies with depth; if you want to increase the draught of a ship longer than 390ft by 1ft you must put in 1ft 3in of depth in order to get it.

To those who have been concerned with the conversion of oil tankers into ore carriers the structural design issue is easy to appreciate. It really means removing the centre portion from the deck of the oil tanker and transferring it to each of the sides. If that were the whole story a perfectly balanced design would be obtained; but because the conversion to ore carrier also introduces very heavy strengthening, the immediate effect is to pull down the position of the neutral axis and destroy the structural symmetry, and a further increase in deck plating is required in order to restore this.

Something should be done in the general design of ore carriers to try to produce greater symmetry. One suggestion would be to make the tank top not necessarily continuous with the whole structure. One way in which the strength might be minimised, but still made quite satisfactory for its local duties, would be to make the stiffening in parts transverse rather than longitudinal. That will help to prevent lowering of the neutral axis. Another point would be to incorporate the second deck in the ore carrier in some suitable position which restores the symmetry for the neutral axis and give better water ballast compartments than using all the hold. That will more rapidly reduce the effective metacentric height in the ballast condition and would allow water ballast to flow overboard by suitable exits as soon as you arrive in port.

I disagree with Mr. Lenaghan's remark about the over-powering of ships beyond the needs of the service, particularly as these ships are turbine-driven and the cost of over-powering is not nearly so heavy as with other types of propulsion. The extra power is of great importance in keeping to schedule and avoiding the obsolescence of the ship.

Dr. J. F. Allan: These vessels are boxes with ends on them. The emphasis is on deadweight, even more so than it is in tanker design, the ships tend to become fuller and it is a real problem to design the ends of the boxes so that the ships will be seaworthy and controllable and reasonably easily propelled.

The more draught we can get, the better it is from the point of view of strength and capacity, and from the point of view of propulsion. Unfortunately, if increased draught were obtained, the fullness of the ship would not be in any way reduced; the owner would want all the extra deadweight he could get, and probably the propulsion would not be much improved. I am surprised that there is not more trouble with the propulsion of these very full vessels at sea than there appears to be. The indications from model testing are that there will be separation of flow and consequent breakdown of flow and of propulsion.

It is interesting to know that the American Lakes bulk ore carriers are considerably fuller than the ocean-going carriers we are constructing and they have coefficients as high as 0·86. These ships are driven hard and I do not think there is any doubt that there is separation at the after end; yet they have a very good efficiency.

I think the efficiency of the self-unloading system is very good, but I am surprised that the loss of deadweight is not more than 7 per cent. At the same time, the equipment represents a large capital investment and it would appear that unless the ships are working on short hauls, as are the American Lakes ships, the investment is barely justified.

Mr. J. Burton Davies: In Table II Mr. Lenaghan lists the berthing restrictions in United Kingdom ports. I feel that its usefulness would be increased if some of the European discharging ports were included; for example, there is a very heavy traffic in Swedish ore from Narvik to Antwerp, and I believe that quite a lot is imported through Rotterdam. If such particulars were added, he might feel that the maximum deadweight and draught of his "eastern" carrier might be slightly increased.

It is quite true that the larger "eastern" carriers are single-purpose ships. But there is one fleet of smaller ships which regularly carry ore from the Baltic to England and return home with refined petroleum products.

(To be continued)

Central Electricity Authority's Bulk Supply Tariff

We learn that the Central Electricity Authority has given notice of a revised tariff for the supply of electricity in bulk to the twelve Area Boards in England and Wales; it came into force as from April 1, 1957. The tariff is in the same general form as that for 1956–57, except that there is an amendment to the fuel-cost variation clause, referred to below. It is explained that the fixed charge per kilowatt of maximum demand, which was £5 in the tariff fixed for 1956–57, has been increased and is at the rate of £5 10s. for the first six months of the year of account and at the rate of £6 for the remainder of that year. The running charge per kilowatt-hour supplied has been reduced from 0·50d. to 0·47d. (with fuel at 60s. per ton). These revised charges reflect the trend of higher fixed costs and lower running costs as further new plant is installed, with the result that capital charges are increased, but operating costs are reduced.

Hitherto, the running charge payable by each Area Board for all the kilowatt-hours supplied to it has been varied in accordance with the average cost per ton of fuel consumed at generating stations in the Board's area. Now that the 275kV supergrid is coming into effective use, substantial bulk transfers of electricity from the low fuel-cost areas to the higher fuel-cost areas will occur increasingly, and the fuel-cost variation clause has, therefore, been altered so that an importing Area Board will, after paying an appropriate charge for the transmission involved, benefit from the lower fuel-cost of production of the imported energy. Because the grid system operates as a unified whole, it is not practicable to locate the source of, or to assess the costs of producing and transmitting, the particular energy imported into any one Board's area, nor would it necessarily be equitable to charge for imports on that basis. Such imports will, therefore, be charged on either of two bases: first, the calculated "residual" fuel-cost, representing as nearly as practicable the average fuel-cost per ton of producing all the imported energy plus 6s. per ton to allow for transmission costs; or, secondly, the area fuel-cost if this is less than the residual cost. The amount of an Area Board's requirements generated by the combustion of fuel within its own area will, as hitherto, be charged on the basis of the area fuel-cost per ton.

Structural Steels for Warship Building with Some Notes on Brittle Fracture

By Sir VICTOR SHEPHEARD, K.C.B., R.C.N.C.

We publish below an abstract of the twenty-fifth Andrew Laing Lecture, which was read before the North East Coast Institution of Engineers and Shipbuilders on March 22. The paper describes the special problems in the hull strength of surface warships and submarines, and refers to the theoretical and experimental research work being undertaken. Special emphasis is given to the work on steel materials, welding and brittle fracture, the object being to avoid brittle fracture in normal structural steels, and the development of high yield steels. Development difficulties are discussed, including welding problems.

IT is thirteen years since one of my predecessors, Sir Stanley Goodall, delivered the Andrew Laing Lecture, and the intervening period has been remarkable for the rapid scientific and technical advances which have taken place in every aspect of naval construction.

During the last war, the sudden and catastrophic structural failure of certain welded merchant ships built under wartime conditions in the United States caused considerable consternation. We appreciated the seriousness of the problem and set up the Admiralty Ship Welding Committee, which has been succeeded by the Admiralty Advisory Committee on Structural Steel. The titles of these two committees themselves indicate some change of view. Initially, the focus was mainly on structural design and welding, but the emphasis has gradually changed until it is now more concerned with the properties of structural steels.

In this country the Admiralty can claim to have played a leading part in the development of new structural steels and in the application of welding to ship construction, and here I refer to Sir Stanley Goodall's lecture of 1944, in which he outlined the history of the introduction of the weldable " D.W." and " S " quality steels. The rapid development of welding for warship construction was essential to meet our wartime requirements and we were fortunate that these steels were adequate for their purpose. Nevertheless, there were a number of incidents which showed that the margins against brittle fracture were small. We also learned the important lesson that wrong conclusions could be drawn from experiments on small-scale models because the phenomena of brittle fracture depend on the actual thickness of the material and also because workmanship, welding and details cannot be properly scaled.

After the last war full-scale trials were undertaken using surplus surface ships and submarines. These revealed some disturbing tendencies. Although the light structures of the small ships of destroyer type generally stood up well to explosive attack and demonstrated the advantages of welded over riveted structures, there was one interesting case where an underwater explosion caused only moderate dishing and no loss of watertightness of the bottom plating, but resulted in the complete shattering of parts of several main transverse bulkheads. Subsequent examination showed that the steel of these bulkheads was of low notch toughness. A further example occurred in underwater explosion trials against a cruiser where the strength deck, of 1in " D " quality steel, and its 8in deep girders fractured across the full width. This was a case of a riveted structure breaking in a brittle manner and not at an abnormally low temperature. The sheer strakes of this ship which were of ⅞in " D " quality, also failed in a brittle manner ; this steel was not of weldable quality and a plug weld initiated a brittle fracture which progressed as such until it reached a riveted lap. It then immediately changed to a ductile fracture. Extremely interesting results were also obtained from underwater explosions against two large targets, U_1 and U_2, constructed to represent sections of side protection systems suitable for capital ships. Here it was necessary to use material up to about 1½in thickness and considerable areas of brittle fracture were found.

All this experience emphasised the necessity for better quality and stricter control of welding, and for the elimination of structural discontinuities. It also proved beyond doubt the urgent need for the development of steels which would not propagate brittle cracks once they had been started by explosive attack or by other causes. The tests also demonstrated that for warship construction, it was necessary to develop stronger steels having high yield points and good weldability in addition to adequate notch toughness.

Developments in Welding Research

In selecting a steel suitable for shipbuilding, we are limited to those welding techniques which are practicable in a shipyard. Also it is necessary to strike a correct balance between weldability and the other physical properties of the steel, such as strength, notch toughness and workability. A great deal of information has now been accumulated which enables us to relate shipyard weldability to the more fundamental tests carried out in the laboratory and so to decide what processes may be recommended for adoption when welding particular steels—or, alternatively, to suggest limits of steel composition which can be accepted with currently available welding processes. The Welding Development Laboratory at N.C.R.E. was not set up primarily to carry out fundamental research, but rather to translate the work of other investigators into acceptable shipyard techniques. From time to time, however, a measure of fundamental research is found to be essential, particularly where there is no incentive for other authorities to undertake it. For example, we have recently set up a large controlled-atmosphere welding chamber. The programme of work for this chamber is particularly important just now, when there is increasing use of the bare-wire, gas-shielded processes for welding steel and aluminium alloys. A vacuum extraction apparatus for the accurate determination of hydrogen in weld metal has also been set up. By " accurate," in this connection, I mean the determination of hydrogen content to 0·001 c.c. per 100 grammes of steel. We confidently hope that these facilities will lead to a better understanding of the influence of hydrogen in causing cracking or fissuring, in addition to permitting a closer examination of commercial electrodes.

Special consideration has been given to the testing of welded joints and structures under explosive and other dynamic loading, and to reproducing the extreme degrees of strain (and overstrain) which must be catered for in damaged warships. Much use is made of the bulge explosion test developed by the U.S. Naval Research Laboratory. In this test, a flat plate or weldment is deformed into a circular hole in a heavy steel die by the pressure from an explosion. The test plates, which are about 2ft square, can be cooled well below ambient temperature, and we can study the crack running tendencies of plate material (for this purpose a very brittle weld bead with a crack-starter notch is placed on the tension face of the plate) and the effect of metallurgical or geometrical discontinuities arising from welds.

There is no doubt that this severe test will discriminate between good and bad butt welds far more satisfactorily than tensile or bend tests —indeed, it has sometimes been found that the latter are quite misleading in placing a number of samples in order of merit.

Great attention has also been given to the development of methods of inspection and non-destructive testing as a means of quality control in the shipyards, and this is followed up by visits to warship builders who may experience welding difficulties. For example, in submarine construction we now conduct 100 per cent ultrasonic examination of all butt and seam welding in the pressure hull, supplemented by radiography wherever doubtful results are suspected. Magnetic crack detection is also employed, particularly for fillet welds. At the same time, we are careful to avoid asking for unnecessarily high standards of examination as they involve considerable effort and are liable to hold up shipyard production.

We have also investigated a number of special welding problems which have been found to be of great importance, particularly with the types of steels used in warship construction. Of these, I will mention only three : (*a*) the effect of welding on galvanised plating, (*b*) the best method of patching holes or fitting insert plates, and (*c*) the crack-starting propensities of hand or automatically welded studs.

Brittle Fracture Research

Research into the problems of brittle fracture has been carried out extensively in America and also by many authorities in this country, notably by Professor Baker and Dr. Tipper at Cambridge and Dr. Wells at B.W.R.A. The work of all these investigators is very closely studied at N.C.R.E. I give some details of the original work done by Mr. Robertson at N.C.R.E. His work has been a unique contribution to the solution of this rather intractable problem and has gained international recognition.

We cannot entirely eliminate the possibility of small defects and incipient cracks, but we must avoid the propagation of brittle cracks into structures where the nominal background stress is low. This feature involves a fundamental property of the steel.

Robertson noticed that in all notched-bar tests yield took place at the root of the notch before propagation of fracture, even in specimens containing very sharp fatigue cracks. Such tests were clearly more closely allied to the initiation of cracking than to its propagation, and Robertson, therefore, set about developing a test to determine the ability of the steel to arrest a high-speed crack. Such a test must be carried out on the full thickness of the material when carrying an appropriate transverse stress—in the same manner as the material would be loaded in a ship. The method eventually adopted employs a test piece 11½in long by 3in wide with a temperature gradient. This gradient is obtained by cooling one end with liquid nitrogen and warming the other end with a gas jet. The temperature range can be varied to suit different materials, but is generally about −60 deg. Cent. at the cool end and +60 deg. Cent. at the warm end, so that a temperature of about 0 deg. Cent. occurs near the middle of the test piece. In the test an operator fires a light missile from a bolt gun, and this will start a crack in the cold end of the test piece which will be arrested when the temperature is high enough to render the material sufficiently tough. The information resulting from these tests is fundamentally different from that obtained in the well-known Charpy, Izod or Tipper tests, in that a graph is obtained which shows arrest temperature, plotted horizontally against applied stress ; at very low temperatures the arrest temperature is dependent on stress ; secondly, there is a region when the arrest temperature is constant and independent of stress, and, thirdly, as stresses rise towards the yield point of the material, the temperature is again stress-dependent. Normal working stresses are on the vertical part of the curve and the position of this vertical line can be obtained from a single specimen tested with a temperature gradient.

Much fundamental work has already been done in connection with this test ; for example, when steel which has been yielded 5 per cent, to simulate cold working in the shipyard, is compared with steel as normalised or as received from the steel works, the arrest temperature will be found to be considerably higher—by as much as 20 deg. Cent. in the case of mild steels. This is most important and shows that a good margin of notch toughness must be available in the

"virgin" steel to ensure adequate performance when it is built into a ship.

In order to simulate service conditions more closely a special machine has been constructed to test plates up to 6ft wide. This machine can apply loads up to 1200 tons, i.e. stresses up to about 16 tons per square inch on a 1in thick plate. It is also capable of testing simple built-up structures such as may be formed by the bottom plating and associated longitudinals. The testing rig leaves both sides of the plates free so that high-speed photographs can be taken during fracture. Strain gauges connected to high-frequency response equipment can be applied to study crack speed and stress variations while the crack is running. Tests on wide plates give results in general agreement with those obtained in the standard crack-arrest test, and tests on casualty material have reproduced very closely the conditions of failure in service.

I should like to quote one example of the fundamental information which is being obtained from these wide-plate tests. The high-speed photography at 5000 frames per second records not only the progress of the crack but the changes in a thin resin coat which reveal surface yield. These photographs show that the surface yield takes place some time before the crack is visible on the surface. The high-speed records of strain gauges attached to the plate surface have shown that there is a relaxation of strain just ahead of the fracture. As the crack progresses the strain increases up to yield, and beyond. The speeds of travel across the plate of this relaxation of surface strain and the appearance of surface yield are not the same. For example, it has been found that for 1in plate, at a high stress value, the former is about 14,000ft per second, and the latter about 6000ft per second. For lower stresses speeds down to half these values have been measured.

Much attention is also being given to the development of what may be called an "acceptable acceptance test." This is an urgent requirement, as the shortcomings of existing notch-bar tests are becoming more and more apparent as they are applied to new steel production. There is, of course, no good reason why small notch-bar tests should accurately predict the crack-stopping properties of steel, which properties are of great importance to the user.

Development of New Structural Steels

The Admiralty's requirements for structural steel are to maintain the required strength and ductility characteristics consistent with good notch toughness and acceptable weldability. These requirements are, to some extent, common also to merchant ship construction. Our requirements are generally more stringent, especially in the realms of explosive loading combined with very low temperatures and in the degree of weight saving which is essential to produce an efficient warship. Here I should like to mention the variability in quality of normal structural steels. I know this is closely allied to the whole process of steel production, but the designer pays a heavy price in efficiency if he has to assume a guaranteed figure, say, of 15 tons per square inch, for yield stress when in fact 90 per cent of all the steel used in a ship has a margin of about 3 tons per square inch above this. Considerable benefits would result to the designer if steel works practices could be improved to reduce the wide tolerances which are at present required in steel specifications.

When the problem of notch brittleness became acute we decided to make a thorough examination of existing structural steels using the latest experimental techniques. A full programme of tests was put in hand on samples of five qualities of steel and in thicknesses from ¼in to 1in. Three plates were tested in each of the selected thicknesses and qualities—a total of forty-five plates. The tests included specification tests, notch toughness tests, weldability tests.

This extensive series of tests led us to the following conclusions:—The level of notch toughness was very variable but on the average was not adequate; the steels employed, except "U.X.W." and for "D.W." in the greater thicknesses, were readily weldable with good low-hydrogen electrodes; "U.X.W." steel was more difficult to weld and required more advanced welding techniques, including preheat; there was considerable variability in composition, weldability being governed mainly by the composition; there was considerable variation in metallurgical structure, non-metallic inclusions, and lack of homogeneity, these features complicating the weldability of the steels; the beneficial effects of normalising on coarse-grained material were confirmed; little or no correlation was found between the various tests for notch toughness and the crack arrest temperature derived from the Robertson tests.

With these results in mind it was decided to draw up new specifications for two structural steels to be known as "A" quality and "B" quality. "A" quality is a notch-tough mild steel and applies to thicknesses of ¼in and over. The specified yield point is 16 tons per square inch up to 1in thick and 15 tons per square inch over 1in and up to 2in thick. "B" quality was intended to supersede both "S" quality and "D.W." quality in all thicknesses and it was hoped that a yield point of 22 tons per square inch could be achieved for thin material and 20 tons per square inch for 2in thickness. It was to have a slightly lower standard of notch toughness than "A" quality and the best degree of weldability consistent with its other properties, provided that the weldability was better than the existing "D.W." steel, which had proved difficult in the thicker plating. This last provision led to an early decision to set the yield stress at 20 tons per square inch for thin plates and 18 tons per square inch for thick plates.

Draft specifications provided for fully killed, grain controlled and normalised material with Charpy V-notch energy tests at −20 deg. Cent. as a guarantee of notch toughness. Discussions took place during 1953 and compromise provisional specifications were agreed which fell short of the Admiralty's original requirements.

Trial casts to these provisional specifications were made by several steel-makers and no great difficulty was found in meeting that for "A" quality. The "B" quality, however, proved more difficult, but several steel-makers supplied material which passed all the provisional specification requirements. Samples of this steel, in plates of ¾in, ¼in, 1in and 1¼in thickness, were subjected to extensive tests at N.C.R.E. These tests proved most revealing, especially as regards notch toughness.

In addition to the mechanical tests extensive metallurgical examinations and weldability tests of several plates were carried out. Conclusions from these tests were: steel with fine austenitic grain size gave better and more consistent notch-toughness results. The results for material of large or mixed austenitic grain size were much more variable; butt-welded plates made of the material rated as best in the various notch-toughness tests gave adequate performance at low temperatures under explosive loading; material, in which both carbon and manganese are at the maximum allowed by the provisional specification, is more difficult to weld than is desirable in a steel intended to be used under shipyard conditions.

The information from the trial casts has been made available to the steel-makers and a modified specification has recently been agreed upon. This will reduce the maximum carbon allowed from 0·20 to 0·19 per cent, and a new criterion based on a "carbon equivalent" will be used to ensure acceptable weldability. It has also been agreed that grain control and normalising should now be a specified requirement for these steels. The Charpy V-notch energy value has been increased to 30ft-lb at −30 deg. Cent. and the Charpy fractures are required to show not more than 75 per cent crystallinity at this temperature.

Before concluding my remarks on this "B" quality steel, I would like to refer to the high ratio of yield stress to ultimate stress which is found in fully killed, grain-controlled steel. From the steel-makers' acceptance test figures, this ratio was found to vary from 0·615 to 0·68, the average value being about 0·65, the higher ratios applying to steel of best notch toughness. This ratio is appreciably higher than has been common in the past for ordinary mild steel and is important in deciding the quality of steel required to give a specified yield stress. We place considerable emphasis on this factor since it is our aim to achieve the best possible yield stress for a given standard of weldability. Any increase in yield enables worthwhile savings in weight of hull structure to be made.

Development of High-Yield-Point Steels

There are two possible methods of producing high-yield steel: (*a*) a low-alloy steel in the "as rolled" and tempered condition—or possibly normalised and tempered; (*b*) a low-alloy steel in the fully quenched and tempered condition. For a given yield stress it is obvious that greater use of alloying elements is required for (*a*) than for (*b*) and therefore the weldability problem will be more acute. For some years, however, it has been necessary to adopt (*a*), as suitable plant for the production of large quenched and tempered plates does not exist in this country.

At first a manganese-molybdenum steel containing about 0·18 per cent carbon and 1·5 per cent manganese was used in the "as rolled" and tempered condition with a guaranteed proof stress of 27 tons per square inch. Welding difficulties were considerable, but it was possible to produce sound structures in material up to about ¾in thick. Later it was desired to increase the thickness to 1in and, in order to meet the specification requirements, the steel-makers found it necessary to increase the carbon to 0·2 per cent and the manganese to 1·6 per cent, which made the welding problem even more difficult. It became necessary to normalise all 1in thick material and to accept a reduction of 2 tons per square inch in proof stress, but there were also difficulties, particularly as regards the degree of non-metallic inclusions in fully killed and grain-controlled manganese-molybdenum steel.

The possibility of using quenched and tempered plates as a solution to the problem is attractive because for comparable welding difficulties the strength can be much greater; alternatively, for equal strength the welding difficulties can be eased; heat-treatment ensures good notch toughness without fully killing and grain-controlling the steel. It is, therefore, likely to be "cleaner."

A thorough examination of some trial plates has been carried out, including the construction and testing under explosive loading of a large fabricated structure. The results of these trials have proved very satisfactory and steel of this type, containing 0·17 per cent maximum carbon and 1·3 per cent maximum manganese and having a yield stress of about 30 tons per square inch is in use. It is quenched from about 900 deg. Cent. and tempered at about 600 deg. Cent. One may be doubtful about welding a quenched and tempered steel, but it must be remembered that a weld is itself a quenched material and, if the correct composition is used in the welding rod, the weld properties can match those of the plate. There may also be some doubt whether the material would survive the cold work which must be imposed in shipbuilding. It appears, however, that it is quite satisfactory, although the total general extension available is rather less than in mild steel. Where extensive elongation is imposed, say, by cold-bending frames either in this material or the "U.X.W." steel previously used, we find it necessary to restore the elastic properties by a low-temperature stress-relieving or tempering treatment in which the original tempering temperature is not exceeded.

"Combustion and Flame."—The first issue has now appeared of *Combustion and Flame*, the quarterly journal of the Combustion Institute. Like the institute, the journal is organised on an international basis, the editor for the British Commonwealth, Europe and Asia being Professor A. R. Ubbelohde, and for the United States of America, Dr. Bernard Lewis. Belgium, France, Germany, Japan and the Netherlands are also represented on the editorial board. The general editorship, in common with that of *Fuel*, in which communications on combustion were formerly published, is held by Sir Alfred Egerton, who, with G. J. Minkoff and K. C. Salooja, contributes to the first issue an account of researches into the influence of the surrounding surface upon the slow oxidation of methane. The annual subscription is £5 5s. or 16.00 dollars, or £8 8s. or 25.00 dollars combined with *Fuel*; it is distributed by Butterworths Scientific Publications, 4–5, Bell Yard, Temple, London, W.C.2, and by Interscience Publishers, Inc., 250 Fifth Avenue, New York, 1.

LITERATURE

Maintenance of High-Speed Diesel Engines. Fourth edition. By ARTHUR W. JUDGE, Wh.Sc., A.M.I.Mech.E. Chapman and Hall, Ltd., 37, Essex Street, London, W.C.2. Price 56s.

THAT there should, since 1936, have been four editions—to say nothing of reprintings—of this volume by Mr. Judge is a sufficient indication of the interest of the theme to those on whose behalf the book has been composed, though—as the author writes in the preface to the fourth (revised) edition—"the treatment of the subject is mostly concerned with the automobile type of compression-ignition engine." The field thus defined is, however, of such importance as to justify elaborate specialist treatment and there is, indeed, information here which will be of interest and value not only to readers in the categories mentioned in the preface, but to engineers concerned with compression-ignition engines of other than automobile type. A considerable fraction of the book is devoted to descriptive particulars of working cycles and engine components without which no treatise on maintenance could be intelligible, and the collection of sectional views both of engines and of components is well designed to clarify the text through which it is generously distributed. We read with particular interest Chapter 3 ("General Maintenance of C.I. Engines") and Chapter 4 ("The Engine Components: Cylinders"). In Chapter 3 typical examples are given of servicing periods, the general interest of these examples being indicated by the following quotation from page 63 :—

"The longest period run by a c.i. engine without anything being done to the crankshaft or big-end bearings with which the writer is acquainted, was that of an A.E.C. oil engine which had run continuously for five years, during which it covered well over 300,000 miles without any attention to the parts previously mentioned. . . . When the engine was stripped down the crankshaft main journals were 0·017in under size. Four of the big-end journals were 0·004in under size and the remaining two, 0·006in. The main bearings showed wear of 0·003in, but the big-end bearings exhibited no measurable wear, with the exception of No. 1, which showed 0·002in."

In order to draw valid comparisons the user of stationary engines has to translate the vehicle mileage into hours of running, and while Mr. Judge does not specify the number of hours during which the truck engine was in actual use, it has been mentioned in a recent paper by the director of research, London Transport Executive, that the average scheduled speed of the London red buses is approximately 11 m.p.h., the annual mileage being 40,000 and the engines running on average about 3600 hours a year. If these particulars correspond with those relating to the engine quoted by Mr. Judge, then this engine would have been running (taking the mileage at 300,000) for, say, 5454 hours per year, which represents rather more than 62 per cent of the total hours per year. While stationary engines of high stamina, well maintained, frequently operate for between 80 and 90 per cent of the total hours per year, 62 per cent is, we imagine, a very high figure for a truck engine, comparing as it does with 41 per cent in the case of the London Transport red omnibus. No doubt the miles run per hour would be considerably higher in the case of the truck than in the case of the London red omnibus and the higher the average miles per hour the lower the percentage of the total hours run per year. At 18 m.p.h., for example, the hours run per year by Mr. Judge's truck engine will be, say, 3333, which is 38 per cent of the total hours per annum. It would have been most interesting had Mr. Judge added, to his interesting account of trouble-free crankshaft bearings in a vehicle engine, particulars of the liner wear in the same engine. It is presumed that the truck engine speed may, like the bus engine speed, have been about 1200 r.p.m., and Mr. Judge quotes tests made by a leading passenger service company showing an average rate of cylinder wear for a straight-run cast iron as 0·00031in per 1000 miles. If we again assume the average speed at 11 m.p.h., this wear would take place in, say, ninety hours, so that in 1000 hours the wear will be, say, $3\frac{1}{2}$ thousandths of an inch. While the medium speed stationary engine should, when in well-maintained condition, show a rate of liner wear not exceeding 0·001in per 1000 hours, it has several conspicuous operational advantages over the automobile engine, outstanding among them being the infrequency of the starts.

We would suggest that in future editions of this useful book further space should be devoted to procedures whereby the cost of maintenance can be reduced. That prevention is better than cure applies with equal force both to compression-ignition engines and to human beings. What we all look for in a book about maintenance is information designed to increase the availability of the engines and reduce the cost of maintaining them. In this connection—and particularly with engines such as those dealt with by Mr. Judge—we can take special note of two requirements, respectively, the desirability of avoiding overloading, and the importance of a high standard of fuel filtration. Regarding the first of these requirements, we should keep in mind the following observation by the director of research, London Transport Executive :—"It is obvious that, apart altogether from consideration of the exhaust products, if increased power is required it is much more economical to use an engine of larger capacity. Not only will fuel consumption be reduced, but because the engine is being operated within its designed capacity, there will be a substantial increase in life between overhauls." As to fuel filtration, only by extreme care in this respect can protection be given to that fuel injection equipment which is the very heart of the engine, and there should be widespread recognition of the fact that in order to avoid worn pump components (such as plungers, sleeves and valves) and worn nozzles, meticulous attention must be given to the fuel filtration.

Motor Vehicle Mechanic's Text Book. By F. K. SULLY, A.M.I.M.I. Temple Press, Ltd., Bowling Green Lane, London, E.C.1. Price 12s. 6d.

THE parallel influences of increasingly mechanised production methods and increasingly high taxation have had their effects not only upon the products but upon the personnel of the motor industry. Many of its present members were trained in a time when a variety of steam, oil and petrol trucks, and cars of every probable or improbable nature, from those with infinitely variable gears to rear-engined streamliners, were produced. The manufacturer expected little more from the servicing organisation than compliance with the instruction book, and the operator was content if the vehicle reliably upheld its maker's intentions. But to-day, when none of the car manufacturers handles more than five-ninths of every £1 paid by the purchaser, there is naturally a difference. The vehicles huddle together under a shroud of conformity and the dealerships are responsible not only for the final approval of each vehicle and its preparation for the customer, but also for finding ways and means to satisfy any requirement not met by a normal vehicle. (There may be no "normal" human being, but it can hardly be denied that the term has a meaning when applied to British cars.) Only when the vehicle has left its maker's works can demands for extra power, greater efficiency at part load, longer life, a better ride, "all-weather capability," sleeping accommodation, or extreme cornering power be tackled. The result is that "know-how," the skill of hands and the judgment of trained observers, is no longer concentrated in Warwickshire and around London, but diffused throughout the country. As an obvious consequence, the problem of training technical staff has become manifestly more difficult, there being no less than 175 technical colleges engaged in instruction preparatory to the City and Guilds examination for motor vehicle service mechanics. When it is considered that the trained technician is called upon to recognise and understand the limitations and failures, actual and impending, of the producers of pneumatic tyres and lubricating oils, optical and electrical equipment, piston rings and silencers, carburettors and shock absorbers, the educational effort involved becomes impressive. There can be no question that there is a place for a book which will record the principles underlying all the many systems and methods involved in the modern car, and be a sound guide for the man charged with diagnosing and rectifying the shortcomings of expensive capital plant.

This, however, is not such a book : it limits itself to the work of mechanics, defined to exclude technicians. Despite the reference in the foreword to the "revised syllabus in Motor Vehicle Technology," under which all examinations will be held after next year, it follows closely the old scheme, being divided between Calculations, Science and Drawing and Motor Vehicle Technology : it differs from the syllabus in omitting all references to metallurgy and the composition of exhaust gases and the matter on *General Servicing and Road Testing*. Nor can it easily be used to follow the integrated (new) course, since the subjects in the first year syllabus not covered include the micrometer, Ohm's Law, soldering, brazing and welding and primary cells. These shortcomings, of course, would be of little consequence to a student working under supervision : a more serious objection to the treatment is that no consideration at all has been given to the user who will wish to proceed to the extension of the mechanics' course and achieve the Full Technological Certificate. There is, perhaps, sufficient material to prepare answers to examination questions in two three-hour papers (though the treatment

of second and third angle projections threatened by the publishers does not appear). But the text is sometimes so facile and superficial as to render more, not less, difficult a fundamental study of the problems involved; the treatment of such a critical topic as the plain bearing verges on the dangerous. It is hard to credit that the index to any work treating upon the light vehicle can fail to include either "corrosion" or "fatigue." When practical matters are raised, the result is sometimes equally unhappy: it is, for example, volunteered that "the camshaft is usually located on the near side," and tyre rotation is advised variously at 5000 and 2000 miles. Discussion is confined to designs and techniques established before World War II: it is unhelpful but desirable for us to comment that this weakness does not prevent it being applicable to the cars of the native English quantity producers.

Digital Calculating Machines. By G. A. MONTGOMERIE. Blackie and Son, Ltd., 17, Stanhope Street, Glasgow. Price 30s.

THIS is an easy introduction to the subject of calculating by machines of the digital as opposed to analogue types. The work ranges over the whole field from the Chinese Abacus through desk calculators, punched card machinery, to electronic computers. Examples of each of the main kind are illustrated. Only the barest outlines have been given of the mechanisms used or electronics employed, as such detail would have been too difficult. The description is for the most part directed to the function and capabilities of the different types for the purpose of engineering as opposed to accounting requirements. The book gives due credit to the valuable work performed for engineers by J. Comrie and his Bureau. The classification into ten keyboard and full keyboard adding machines and four rule calculating machines is obviously useful and the main consideration of the book. The author has at one point usefully digressed to show the value of window cards for laying out calculations, such as those involving solving simultaneous equations by use of matrices.

There has been comparatively little literature published on conventional punched card machinery and these chapters might well have contained more material. Whilst these chapters whet the appetite for more, the references for further reading all too often are to manufacturers' catalogues. Such sales literature tells all too little of the real capabilities of the machines, usually saying little more than the obvious function, such as sorting, punching, multiplying or tabulating and a rough estimate of speed, and manufacturers' technical literature tells little more than the adjustments required. A current loose-leaf compilation to which reference might usefully have been made is "Office Automation," published by Automation Consultants, Inc., of U.S.A., which while directed to the business field nevertheless gives the sort of information that would assist a reader to expand on those chapters for which the main reference for further reading is manufacturers' catalogues. Further, the annual Business Efficiency Exhibition is the one place in England where all these machines are on show and can be handled. Comparable exhibitions are regularly held also in Paris and Hanover.

The author brings out the fact that whilst the keyboard machines will always be with us, and useful for lesser calculations, many engineers, even when the circumstances justify a computer, are lucky to have even the part-time use of punched card machinery, and that it will be many years yet before managements have been educated to the point where they are ready to expend capital on having the calculations they require performed with the speed and accuracy possible with the higher speed electronic calculators. Whilst this is generally true, some enlightened managements have already installed computers for scientific calculations.

The novice to calculating will find here a broad picture, and will not be confused as all difficulties of either mathematics or construction of machinery have been omitted.

Essential Factors in the Future Development of the Oil Industry. Edited by G. SELL. Institute of Petroleum, 26, Portland Place, London, W.1. Price 40s.

THIS volume is an account of the proceedings of the summer meeting of the Institute of Petroleum, held at Torquay, and contains the eight papers presented at the meeting, together with the discussions. The papers read at the meeting cover the subject of the increasing gap between energy requirements and the fuels needed to fill the gap, and point the way to a solution of the problem. They discuss, in particular, world energy outlook, including atomic energy; oil demand and oil resources; the changing pattern of world oil movements; developments in oil refining; oil as a source of chemicals, and the financial factors in oil development. The first paper includes graphs showing the world energy demand between 1955–75 in terms of tons of coal equivalent, and the second paper examines various points related to atomic energy, such as fuel, location of reactors, economics, probable uses and the potential scale of application. Paper No. 3 reviews past developments in oil demand and forecasts future trends in total and area consumptions, while the next paper reviews the increase in proven reserves of oil and sets forth a possible pattern of production in 1965 and 1975. The effect of the Middle East becoming a major source of world oil supply upon transport is discussed, together with the anticipated growth of tankers, while the next paper deals with refinery techniques, capacity and location. The seventh paper has for its thesis the search by the chemical industry for simple raw materials for the production of organic chemicals and the final paper discusses the financial aspects of the expansion in oil operations over the next twenty years.

The World's Tankers. By LAURENCE DUNN. Adlard Coles, Ltd., 7, Brunswick Place, Southampton. Price 35s.

THIS book is a record of the development of the oil tanker from the early designs to the modern ship transporting thousands of tons of oil. Several of the pioneer vessels are described and some account is given of the beginnings of two famous tanker fleets, while succeeding chapters refer to sailing ships and barges built to carry oil. The growth in both numbers and size of tankers during the first two decades of the century is traced, followed by details of the developments in design and construction after the first world war. There is a chapter devoted to the various designs of tankers built during the second world war, followed by one dealing with post-war developments, and an account of the evolution of the modern whale factory ship. Harbour, coastal and river tankers are grouped together, as are also the special tankers which carry other classes of cargo, while a separate section includes examples of the super-tankers. The book concludes with general particulars of the largest of the tanker fleets and contains many illustrations of a large number of the tankers described.

Technical Reports

Massiv Brücken. Teil I: Platten-und Balkenbrücken. By H. Unger. Leipzig: B. G. Teubner Verlagsgesellschaft, Goldschmidtstrasse 28, Leipzig, C.1. Price DM. 26.—This German textbook on masonry and concrete bridge construction is written for the younger engineer. Part I, which has now appeared, deals with slab and girder bridges and surveys the field from the early Roman masterpieces to the modern technique of prestressed concrete. The historical review lends force to the plea for effective collaboration between engineer and architect. In the following main section the underlying mathematical and design principles are dealt with in detail.

Calcul Numérique, Calcul Physique. Application à la Thermocinétique. By P. Vernotte. Publications Scientifiques et Techniques du Ministère de l'Air, No. 319. Service de Documentation et d'Information Technique de l'Aéronautique, Magazin C.T.O., 2, Avenue de la Porte-d'Issy, Paris (15e). Price Fr. 2200—The present work on heat transmission falls into two parts. In the first, entitled "Seven Lectures on Thermokinetics," Gen. Vernotte deals with the theoretical aspects of steady and unsteady heat flow in materials, radiation, as a movement of electro-magnetic energy, being excluded. The second main section consists of a very full and detailed discussion of the methods of numerical calculation as distinct from formal solutions.

Jahrbuch der Elektrowärme. Issued on behalf of the German Committee for Electric Heating Applications by Professor Dr.-Ing. H. Müller. Essen: Vulkan-Verlag Dr. W. Classen, Hollestrasse 1g, Essen, German Federal Republic. Price DM. 64.—Since the appearance some twenty-five years ago of Professor Dettmar's handbook, the only other books which cover electro-thermal practice in a general manner were the volumes of collected reports from the three international congresses in this field which have taken place, the last one in Paris in 1953. The present volume covers the period since that congress and so fills a gap in the documentation, a fact which will be the more welcome as literature dealing with the industrial applications of electrical heating is notoriously widely scattered. The subject matter is arranged according to industries, and there are chapters dealing with general problems of furnace construction, electricity supply, and domestic and agricultural applications. In addition, the volume contains abstracts from the papers given at the Paris congress, and a survey of papers which have appeared in the technical press since, with particular reference to Germany, Austria and the Netherlands.

Books Received

Industry and Press Relations. By Peter Hayle. Staples Press, Ltd., Mandeville Place, London, W.1. Price 12s. 6d.

Science and Economic Development. By Richard L. Meier. Chapman and Hall, Ltd., 37, Essex Street, London, W.C.2. Price 48s.

The Theory of Suspension Bridges. By Sir Alfred Pugsley. Edward Arnold, Ltd., 41, Maddox Street, London, W.1. Price 42s.

Television Receiving Equipment. Fourth edition. By W. T. Cocking. Iliffe and Sons, Ltd., Dorset House, Stamford Street, London, S.E.1. Price 30s.

The Electrical Trades Directory, 1957. Published annually in January by *Electrical Journal*, Bouverie House, 154, Fleet Street, London, E.C.4. Price 63s.

Weather Map: An Introduction to Weather Forecasting. Fourth edition. H.M. Stationery Office, York House, Kingsway, London, W.C.2. Price 10s. 6d.

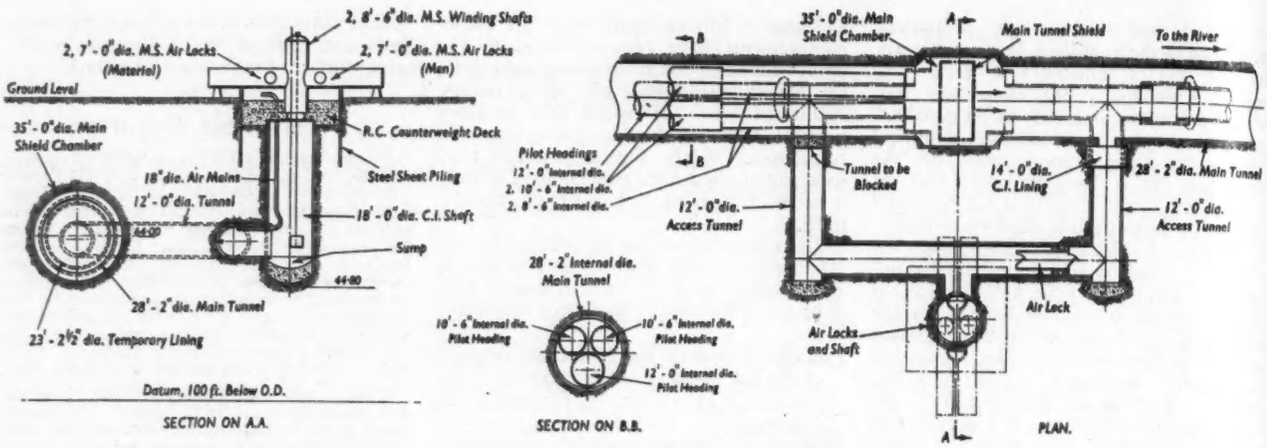
Petroleum and its Products. By J. H. Van der Have and C. G. Verver. Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, Kingsway, London, W.C.2. Price 50s.

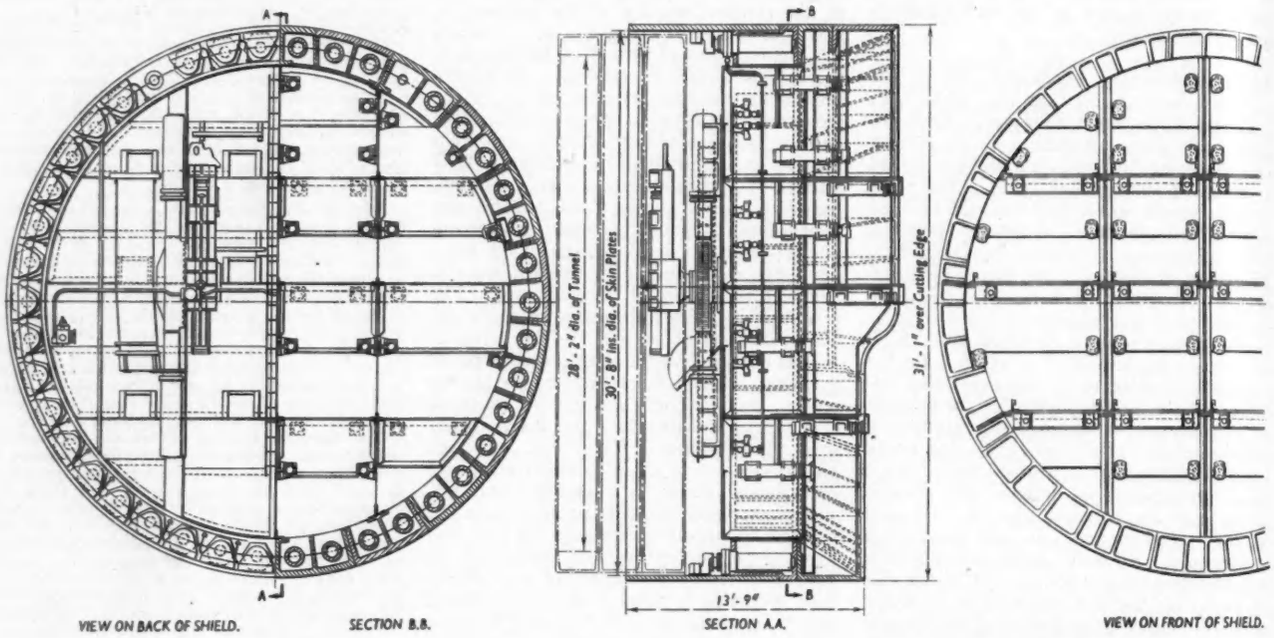
The Specification and Management of Materials in Industry. By C. H. Starr. Thames and Hudson, Ltd., 30, Bloomsbury Street, London, W.C.1. Price 21s.

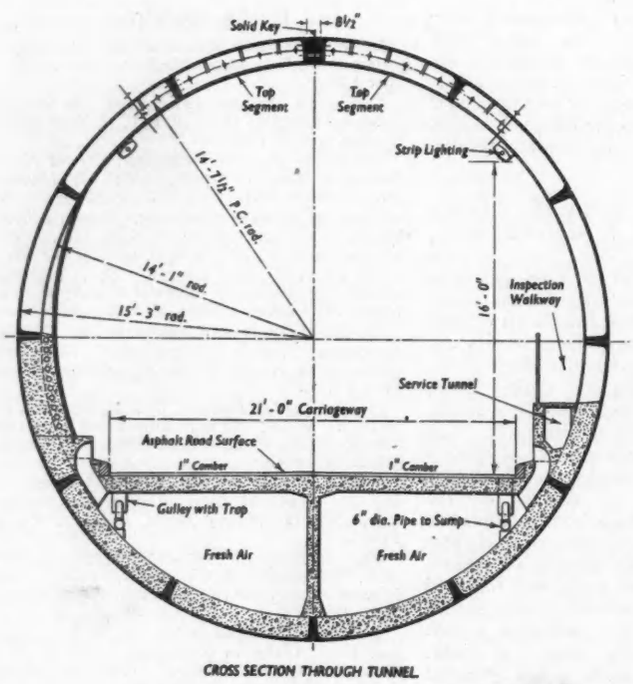
The Analysis of Engineering Structures. By A. J. S. Pippard and J. F. Baker. Third edition. Edward Arnold, Ltd., 41, Maddox Street, London, W.1. Price 60s.

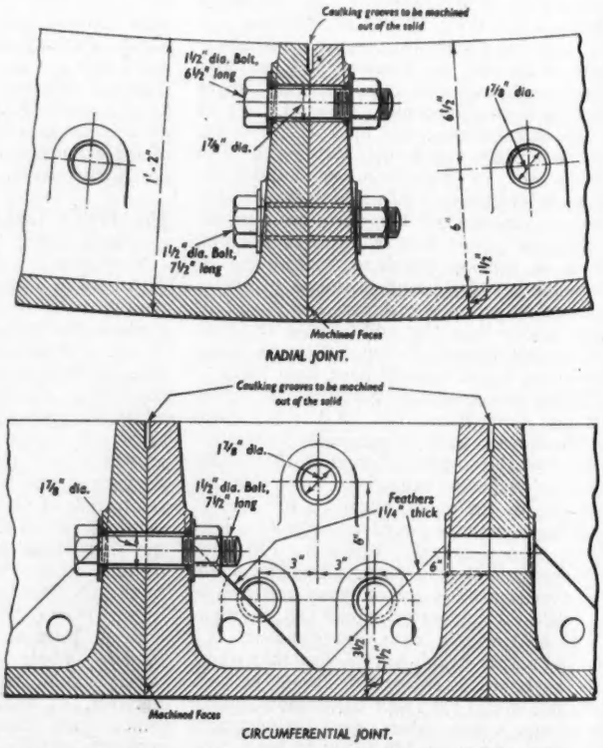
Boiler Plant Instrumentation. By W. R. L. Kent and D. C. Gunn, in collaboration with G. F. J. Murray. Heywood and Co., Ltd., Ingersoll House, 9, Kingsway, London, W.C.2. Price 21s.

Chemical Engineering Practice. Vol. 3: Solid Systems. By Herbert W. Cremer and Trefor Davies. Butterworth's Scientific Publications, 88, Kingsway, London, W.C.2. Price 95s.









Constructional details of the Dartford-Purfleet tunnel. (Top) Shaft and shield chamber layout on Essex bank. (Centre) The tunnel shield. (Bottom) Tunnel cross-section and segment details

Tunnel Under the Thames between Dartford and Purfleet

On March 21, Mr. Nugent, Joint Parliamentary Secretary to the Ministry of Transport and Civil Aviation, inaugurated the main works of the Dartford-Purfleet road tunnel. The tunnel will have a single carriageway 21ft in width and will be driven under the Thames for a distance of 4700ft.

A CEREMONY was held on March 21 to mark the start of tunnelling work on the Dartford-Purfleet road tunnel. Although described as an "inaugural ceremony," the stage reached now is that of commencement of compressed air working for the main tunnel drive. The scheme dates from the nineteen-thirties and the pilot tunnel was actually driven before the war. However, the economic policy of successive Governments since the war has prevented a resumption of work on the scheme until recently, and the main contract for the tunnel itself was let nearly a year ago. Since then preparatory work has been in progress to refurbish the tunnel shields and the surface installations, using much of the pre-war plant, supplemented by other plant newly installed.

The tunnel will be the first major work of its kind to be built in this country since the war. Much tunnelling work has been completed since the war, of course, but, apart from tunnelling works for national defence the extent of which is secret, it has been mainly rock tunnelling, the Scottish hydro-electric schemes, the Woodhead railway tunnel and the Haweswater aqueduct being the most notable examples. Compressed air tunnelling works have been much more restricted, and have included only a handful of projects, such as the Clyde water tunnel and the Tyne pedestrian tunnel. In fact, no road tunnel of comparable size has been constructed in this country since the completion of the Mersey tunnel.

The Dartford-Purfleet tunnel will provide a direct road link across the River Thames 15 miles east of London; at present the only crossings below the Blackwall tunnel are the Woolwich and Gravesend-Tilbury ferries. The principal statistical data for the tunnel are listed in the accompanying table. These figures give an idea of the scale of the work; the drawings on the opposite page show some of the constructional details. It may be observed that, generally speaking, the tunnelling follows accepted practice for this class of work. There are, however, one or two innovations, and although it is too early yet to give a complete account of all the design problems and methods of construction, we have tried to indicate in the ensuing description those points which are of special interest.

The tunnel design has obviously been governed by the lapse of two decades since work was first started, a period during which there has been considerable alteration in accepted standards for highway tunnels. The tunnel shields were already in position before the war, when work was suspended. They have since been completely reconditioned. Their construction is indicated in the drawings. Each shield weighs about 300 tons and has sixteen working cells at the face and a cast steel cutting edge. There are hydraulic jacks in each cell for use in supporting the face in soft ground; hydraulically operated extensible working platforms are provided to facilitate excavation when the face is in hard ground. At the rear end of the shield there are two hydraulic erectors for the cast iron segments. Each of these erectors can be rotated by a rack and pinion, and the arm carrying the segment extended to place it in its final position. The jacks at the face and these erectors are operated by a hydraulic system at a pressure of 1000 lb per square inch. However, the forty main jacks which push the shield forward operate at a higher pressure, namely 6000 lb per square inch.

The strata through which the tunnel will pass are entirely water-bearing, being in descending order silt, gravel and chalk. It is expected that a rate of progress of about 5ft or 6ft a day will be reached, and pressures of 5 lb to 35 lb per square inch will be utilised during the operation.

Data for the Dartford-Purfleet Tunnel

Total estimated cost	£11,000,000 approx.
Amount of present contract	£6,000,000
Length of tunnel	4700ft
Length of open cutting at entrances	1500ft
Overall length	4 miles (subject to parliamentary approval to extend northern approaches to A13)
Lowest point below high water	108ft
Tunnel gradient on each side	1 in 28
Tunnel gradient in centre	1 in 485
Internal diameter of main tunnel lining	28ft 2in
Carriageway width	21ft
Flanges of lining segments	14in deep
Total weight of cast iron for main tunnel lining	34,000 tons
Number of bolts required for lining	260,000
Weight of lead for caulking lining	160 tons
Total quantity of tunnel spoil	3,000,000 cubic feet
Diameter of pilot tunnel completed in 1938	12ft
Capacity of compressors	42,000 cubic feet per minute (total installed capacity including stand-by plant)
Weight of each shield	300 tons
Pressure exerted by shield rams	6000 lb per square inch
Total thrust of shield	5000 tons
Roads which will feed the tunnel	London-Rochester Road A2, London - Tilbury trunk Road A13

Tunnel Design

The tunnel cross-section, shown opposite, illustrates one of the principal problems of layout, viz. to install the maximum width of carriageway practically possible within the diameter imposed by the pre-war tunnel shield. The pre-war design envisaged a carriageway width of 20ft and it has been possible to increase this figure to 21ft. Ventilation ducts are to be installed beneath the carriageway, with services as indicated. At the present time the final designs of the tunnel lining, the ventilation plant, and the lighting, have still to be worked out. The ventilation system has been designed on the basis of a supply of 130 c.f.m. of fresh air per foot run of the tunnel. The system of fire-alarm, communications and atmosphere-control will embody the most recent practice.

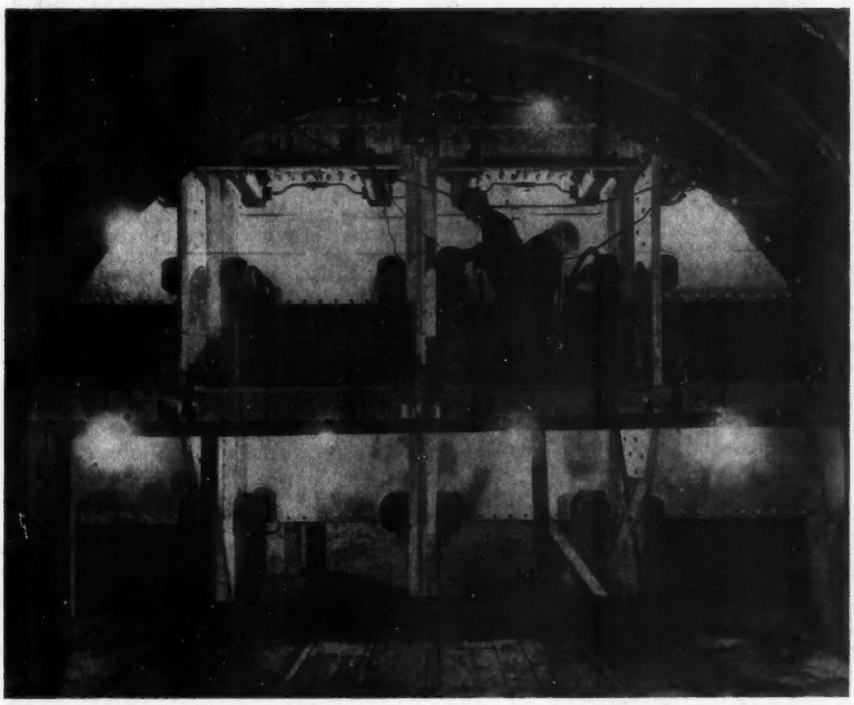
The standard width of the cast iron segments will be 18in, but where the tunnel is entirely in chalk, 2ft 6in segments will be used, allowing some economy in joints. The arrangement of the segments is a symmetrical one, with a solid key bolted in at the top; the bolt holes round the circumference are evenly spaced, the number being divisible by four, thus giving a simplified arrangement which allows stepping of the key, and avoids complication on vertical and horizontal curves. Grouting behind the lining will be carried out up to pressures of not less than 60 lb per square inch greater than the prevailing air pressure in the tunnel.

One other aspect of design should be mentioned. A figure of over 2,000,000 per year has been quoted for the vehicles using the tunnel, but we understand traffic studies are at present in progress under the direction of the County Surveyor of Kent. Parliamentary legislation is still needed to amend the pre-war figures for tolls, and hence a traffic estimate based on present-day conditions is needed; furthermore, the approach roads are planned on a more extensive scale than in the original scheme, and parliamentary approval is needed for them. It is planned that the northern approach should start at a roundabout at the Southend arterial road, A13, and be carried over A126 on a viaduct. Dual carriageways will be constructed on the approach roads, converging to the single 21ft of the tunnel carriageway after the toll booths have been passed. This arrangement lends itself to the possible duplication of the tunnel, should the traffic grow sufficiently to demand it.

Constructional Methods

Perhaps the greatest possibilities for improvements in constructional technique for underground work of this class lie in methods of ground treatment. The use of the "Soletanche" system of grouting on the Dartford-Purfleet tunnel illustrates this point, for this particular application is novel, although the "Soletanche" method, which is of French origin, has been used fairly extensively in other countries on works of a different nature, principally to obtain an impermeable "cut-off" for a dam or reservoir.

This form of grouting has been carried out over a length of tunnel at each river bank. The gravel stratum is characterised by an irregular



Part of the working face of the tunnel shield in the shield chamber on the Dartford side is shown here, as seen from the pilot tunnel. When the tunnel is put under air pressure a concrete ring in front of the shield will first be cut away to start the main tunnelling work

distribution of materials ranging from fine sand to 3in flint cobbles. This stratum is from 5ft to 15ft in thickness and the coarse and fine material is distributed in it unevenly. It is thus highly permeable and its uneven nature makes it unsuitable for successful treatment with Portland cement grout, since the grout tends to segregate in the coarser areas.

Thus, on each side of the tunnel, where it passes through the gravel stratum as it dips down to its underwater level, some additional form of treatment was desirable so as to limit the loss of compressed air through the gravel. Leakage of air through the gravel becomes significant at the point where the top of the gravel stratum is above the mid-point of the tunnel (where the gravel is below the mid-point the differential air pressure is likely to be negligible) and continues until the tunnel is completely into the chalk, with a cover of about 6ft of chalk over the crown. Over this distance, therefore, on each bank, the gravel has been treated, principally from grouting tubes sunk from jetties built out into the river. The treated areas have been chosen so that the ground round the tunnel is, from the point of view of impermeability, like a series of inverted " boxes." When the levels are suitable, for instance, the impermeable silt forms the top of the " box," and the treated gravel the sides and ends ; this is varied according to the relative levels of the tunnel and the gravel. This application of the " Soletanche " system has recently been described by Mr. J. Kell in the *Chartered Civil Engineer* : because of the interest of the process we reprint an abstract from his description in the following paragraphs.

" The principle of the method is that the voids in the alluvial material are sealed by the injection, in successive stages, of composite grouts designed to penetrate deposits of differing permeability. The main material employed is Bentonite, a processed clay with a high liquid limit and thixotropic* properties which render it penetrative of soils in which the grain size is too small to admit a Portland cement grout. By combining Bentonite in differing proportions with Portland cement, and with soluble silicates and other reagents, it is possible to prepare grouting fluids suited to the particular characteristics of the ground as disclosed by sampling. The larger voids are filled first with a clay-cement grout. This is followed by a clay-chemical grout which penetrates the finer materials. The mechanical strength of the material treated is not increased to any marked degree but the soil is rendered impermeable.

" Grouting is carried out from ground level through a series of vertical holes spaced at 10ft intervals over the area to be treated. First, a cased borehole 3in or more in diameter is sunk to the bottom of the gravel at each point, using conventional methods. Inside this borehole is placed a sleeved injection tube, illustrated herewith, consisting of a 1½in diameter steel tube with groups of radial perforations arranged at intervals of about 12in, each perforated section being covered by flexible rubber sleeve that fits closely around the tube.

" When the sleeved tube or *tube à manchettes* has been inserted, the 3in diameter outer tube is withdrawn from the borehole and simultaneously the space around the sleeved tube is completely filled with a special grout. The latter does not, however, penetrate the ground, but forms a watertight plastic seal around the sleeved tube.

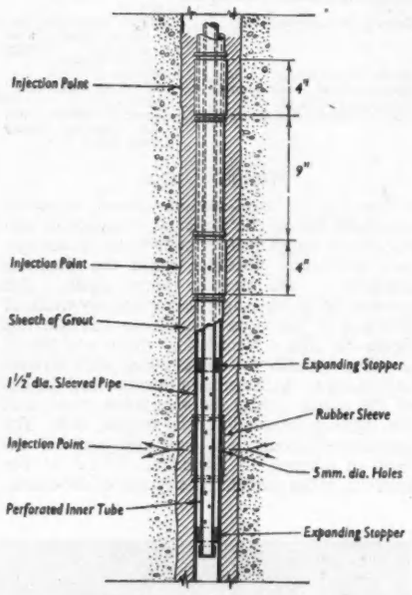
" A 1in diameter tube, connected by flexible hose to the grout pump, is then inserted inside the *tube à manchettes*. The bottom end of this inner tube is closed, but its lower portion contains a short perforated section. Above and below this are expanding stoppers, which form a tight seal against the inner surface of the *tube à manchettes*. By raising or lowering the inner tube, its perforated end can be presented opposite any of the sleeved perforations in the *tube à manchettes*. When grouting fluid is pumped into the inner tube, it emerges into the space between the isolating stoppers, lifts the rubber sleeve and, rupturing the sheath of special filling surrounding the *tube à manchettes*, flows into the ground through the fissures thus formed.

" Normally, injections commence at the bottom of the gravel and proceed upwards. After injection, the inner tube is withdrawn and the sleeved tube is thoroughly washed out so that successive injections can be made.

" It is a marked advantage of the method that once the sleeved tubes have been installed in the ground repeated applications of grouts of different characteristics can be made at any interval of time without the expense of reboring. A further advantage is that separate injections can be made at short vertical intervals. The grout travels radially outwards from the injection tube at the chosen level, and this makes possible selective application suited to variations in the bedding.

" Results of tests indicated that the clay-cement grouting had reduced the permeability from the order of 3×10^{-1}cm to 1×10^{-2}cm per second in the natural state to 5×10^{-4}cm to 1×10^{-5}cm per second when grouted ; i.e. to a thousandth of its original value, or from that of typical Thames gravel to that of a silt."

One other constructional method will be used for the first time, as far as we are aware, on this tunnelling job, viz. pumping out the tunnel spoil in the form of slurry. Excavated spoil will be recovered from the base of the tunnel shield by a " Duckbill " shaker conveyor, and then carried by a belt conveyor to a crusher. There will be a screen, for rejecting oversize material at the boot of the conveyor. Crushed spoil will pass into an agitating tank, and water will be added, the resulting slurry then being pumped up to the surface and to settling ponds. The crusher, with the tank below it, and the pump will be rail-mounted, and will be moved forward after about 150ft of tunnelling progress, this distance being covered by " telescoping " the conveyors. This arrangement is being adopted partly because the pre-war shaft layout (illustrated on page 530) incorporated right-angle bends which were too constricted to allow rapid transfer of muck skips, but it also eliminates passing the skips through the air locks. The spoil will be used to form embankments protecting the tunnel cuttings against river floods.



Sleeve tube for grouting permeable stratum

In 1938 (THE ENGINEER, January 21, 1938), we gave a full description of the compressor plant installed at the tunnel. The Robey compressors which we described at that time were used for constructing the pilot tunnel, and were subsequently transferred to other work, including, we understand, the construction of the Tyne pedestrian tunnel. The plant now installed consists of three reciprocating compressors delivering 5000 cubic feet per minute at 45 lb per square inch and consuming 750 h.p. at 275 r.p.m., electrically driven with power from the grid. They were supplied by Alley and MacLellan (Polmadie), Ltd., and the electric motors, which operate at 3·3kV, were supplied by Crompton Parkinson, Ltd. The standby plant consists of six diesel-driven compressors, each of 970 cubic feet per minute capacity at 40 lb per square inch. The diesels are Ruston and Hornsby, Ltd., machines, and the compressors are by Broom and Wade, Ltd. This installation, as detailed, is installed at each of the two working shafts. Hydraulic plant at each shaft consists of high and low-pressure systems for each shield as follows: a 6000 lb per square inch pump delivering 12½ g.p.m. and connected directly with the shield jacks ; a 1000 lb per square inch pump delivering 55 g.p.m. to a hydraulic accumulator of 67 gallons capacity, for the low-pressure shield services. All the hydraulic equipment was supplied by Tangyes, Ltd. The plant above ground at each shaft also includes the control room for all services entering the tunnel, and medical air locks and rest rooms for the compressed air workers. On the Dartford bank these installations are complete, but on the Purfleet bank some work remains to be done before the main drive can be started.

The shaft drawing also shows the arrangement of air locks. There are four locks—for men and materials—at the top of the shaft, and at the base in the access tunnel a second pair of air locks. There is also an air lock in the centre of the pilot tunnel, to take care of differences in pressure between the two faces, with a drainage sump and pumps close by. The shafts are each about 80ft deep. The arrangement at both shafts is generally similar. Two air locks—a " man " lock and a " materials " lock—will be in use for most of the time, but, at times, as constructional progress dictates, one " leg " of the access tunnels will be blocked off and there will be only one lock in use. The drawing shows such a stage of the work.

There are various operational routines which will be followed in using these locks, but during most of the work the underground locks only will be in use. A point of special interest here is that decompression will be controlled automatically. The instruments controlling decompression will be set according to the pressure of the tunnel and the time during which the men concerned have been exposed to the pressure, thus initiating an automatic cycle of decompression in accordance with accepted medical practice for decompression.

When the shield on the Dartford side has advanced clear of the chamber, a second shield will be built for a landward drive of 1240ft. It is thought that this method may not prove to be necessary on the Purfleet side, where the length of tunnel landward of the shield chamber is only 640ft. Here it is planned that two further pilot tunnels will be constructed, as shown on the drawing, and then the three pilot tunnels will be broken out to the full section.

The programme for the Dartford–Purfleet tunnel works envisages completion of the scheme in about five years' time. The Ministry of Transport and Civil Aviation's consulting engineers are Messrs. Mott, Hay and Anderson and Messrs. Coode and Partners, acting jointly. The main contractor is Edmund Nuttall, Sons and Co. (London), Ltd. The ground treatment is being carried out by Soil Mechanics, Ltd.

LEICESTERSHIRE WORK STUDY GROUP.—A Work Study Group has been formed in Leicestershire to meet the demands of those engaged in the practice of work study in local industry, commerce and agriculture. This group, which now has a registered membership of seventy, intends to keep closely in touch with developments in all branches of industry, and to assist in extending the appreciation of work study. People who are interested in, but not directly practising, work study, are invited to join as affiliate members. The secretary of the group is Mr. G. V. Taylor, 279, Narborough Road, Leicester.

LARGE CAPACITY SOLENOID-OPERATED VALVES.—A solenoid valve designed to handle large flows at high pressures, which is now being manufactured in a range of sizes from ¾in to 2in bore by Teddington Industrial Equipment, Ltd., Sunbury-on-Thames, Middlesex, is intended for use in hydraulic, pneumatic or similar applications. These valves are of two-way piloted piston construction and are suitable for the control of chemically inert fluids or gases up to 1650 lb per square inch. Each valve comprises two main assemblies—a solenoid-operated pilot valve and a piston main valve—and the valves can be arranged either to open or to close when energised.

* The viscosity of thixotropic substances is reduced temporarily by mechanical agitation.

Electrical Engineers Exhibition

No. I

The Electrical Engineers Exhibition at Earls Court will be opened on Tuesday, April 9, by the Minister of Education, Lord Hailsham, and will remain open to the trade until April 13 from 10 a.m. to 7 p.m. daily. There will be a large stand devoted to the theme of training and education in the industry and Government services in which a number of organisations will be co-operating, including The Illuminating Engineering Society, The Central Electricity Authority, the G.P.O., the B.B.C., the Royal Navy, and the Royal Air Force. A total of 380 exhibitors will be taking part in the exhibition this year. Some of the exhibits are described here.

Electrical Research Association

MUCH of the research done on surges in electrical supply systems and their effects on power plant is necessarily carried out with artificial surges. Generally, the higher the system voltage the higher are the levels of surge voltage and energy required. The Electrical Research Association, Leatherhead, Surrey, has surge generators capable of producing a wide range of artificial surges in the laboratory and in the field. One of the smaller generators will be exhibited ; it was constructed by the E.R.A. making use, where possible, of readily available radio components. It is used for general purposes where moderate voltage and energy suffice. The nominal maximum voltage is 200kV and the overall capacitance is 0·01μF. giving 0·2kW sec. of stored energy.

A 2·8 MV generator was recently installed in the laboratory ; with a stored energy of 130kW sec. it is the largest surge generator in Britain which is available solely for research purposes. Other equipments include a transportable generator specially suited to field tests, rated at 1·3 million volts (8·45kW sec.) and a bank of capacitors rated at 15kV (20·25kW sec.) primarily used for synthetic testing of circuit breakers.

Good progress has been made recently in understanding the mechanism of lightning discharges and in the development of lightning protective devices. One of the more important matters upon which information is urgently needed is the frequency of lightning discharges to earth in various parts of the world. Instruments capable of yielding this information are available, but they are costly and require skilled operation. The lightning flash counter* (to be exhibited here) is, however, an inexpensive instrument embodying an automatic counting mechanism ; because of its modest cost it should be possible to install it in numbers in various parts of the world to give strictly comparable data which can be analysed by the Electrical Research Association. The flash counter is designed to record lightning flashes to earth within a distance of about 25 miles. It consists, essentially, of a cold-cathode valve connected, through a special input circuit, to an outside aerial. All components are suitable for use in the tropics, including the two dry batteries which render the instrument independent of external electricity supply.

The circuit (Fig. 1) operates as follows. The

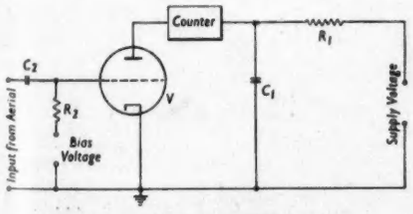


Fig. 1—Lightning flash counter—E.R.A.

capacitor C_1 is charged through resistance R_1 to a voltage just insufficient to trigger the thyratron valve V. When a positive field change occurs a positive impulse from the aerial is transmitted to the grid of V ; V fires, and the condenser discharges through V and the counter causing it to operate. When the discharge current becomes sufficiently low V ceases to conduct and resetting is thus automatic with the time constant R_1C_1, which is approximately one second. Sensitivity may be controlled either by changing the bias voltage or by including a potentiometer across C_1.

If the circuit is to respond only to discharges to earth it is necessary for it to operate only on rapid electrostatic field changes, and thus any response to very low frequencies is to be avoided. Discrimination against high frequencies is unnecessary since, with an appropriate sensitivity setting, there is little chance of spurious functioning on radiation fields accompanying the slow variations in electrostatic field ; for the range considered (0km to 40km) these are much smaller than the rapid electrostatic field changes caused by the return stroke. In practice an absence of any considerable response below about 100 c/s to 200 c/s is desirable. The frequency selectivity in the grid circuit, besides depending on the values of C_2 and R_2, is also governed by the capacitance and leakage resistance of the aerial and the capacitance of the input leads.

Promising results have been obtained with this instrument during tests made at Cambridge, as reported by Dr. E. T. Pierce of the Cavendish laboratory.† It is thought that these results justify further observations in more suitable localities where greater frequency of thunderstorms should enable more exhaustive trials to be made.

* Developed by the E.R.A. in collaboration with the Cavendish Laboratory, Cambridge.

† E.R.A. Report Ref. IB/T20.

Ferguson Pailin, Ltd.

The main equipments to be shown by Ferguson Pailin, Ltd., Higher Openshaw, Manchester, 11, will be a 132kV outdoor air-blast circuit breaker, type "CA10," and a 33kV, 1000MVA indoor metal-clad switch unit, type "VSLP9."

The 132kV air-blast circuit breaker consists of three single-phase units ; each unit is mounted on a chassis which incorporates a built-in solid-drawn air receiver, supporting three porcelain insulators. The main insulator of these three carries three interrupters in trefoil formation and contains the porcelain air inlet pipe which connects the interrupters to the blast valve. Of the two smaller insulators the middle one constitutes the drive shaft for the isolator contact arm and the outer one supports the isolator fixed contact and line connection.

The blast valves, which control the air supply to the interrupters, are mounted at the base of the air inlet tubes and are of aluminium alloy made to simplify handling and maintenance. All three blast valves are operated by a single control unit, there being only one trip coil for the three phases.

This design of air-blast circuit breaker makes use of porcelain insulation throughout and the main insulators as well as the interrupters are standardised to be adaptable for other voltage ratings. Control of voltage distribution is by linear resistance. The isolator is arranged to operate sequentially and the drive mechanism is provided with fluid damping. The arrangement of the circuit breaker provides for easy conversion to auto-reclose.

The "VSLP9" switch unit is a further development of the vertically isolated design introduced by Ferguson Pailin, Ltd. It is intended for use in power stations and primary substations at ratings up to 1000MVA and 1600A. The equipment provides for rapid fault clearance, integral earthing, positive and foolproof interlocking, together with visual indication of all operational positions, minimum space requirements and small oil volume. It is designed to comply in all respects with the requirements of British Standard 116 : 1952.

Another exhibit is the company's "OFS" oil-immersed fuse-switch designed for indoor or

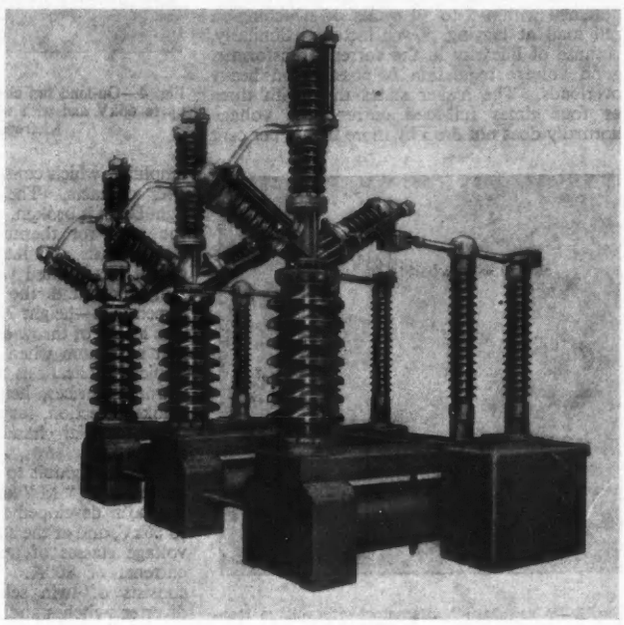


Fig. 2—"CA10" air-blast circuit breaker for 132kV—Ferguson Pailin

outdoor service. This small steel-encased, fully automatic equipment is capable of controlling feeder and transformer circuits on 6·6kV and 11kV systems where the fault level does not exceed 250MVA. Fault currents are dealt with by three "trip all phases" h.b.c. fuse links mounted in a readily insolatable fuse carrier which is fully interlocked with a simple operating mechanism to ensure safe operation. Normal load currents can be interrupted or made on the fuse carrier contacts. In combination with the Ferguson Pailin "IB4" oil switch it provides a ring main equipment which can be extensible or non-extensible. A variety of such arrangements is available to suit the cabling, operating and site layout conditions.

Arthur Lyon and Co. (Engineers), Ltd.

A new development based on the standard "Stamford" self-regulating alternator is being shown by Arthur Lyon and Co. (Engineers), Ltd., 6, Carlos Place, Grosvenor Square, London, W.1. The existing standard machine is, briefly, an alternator provided with phase and load compensation, giving characteristics similar to those of a compound-wound d.c. generator. In the present development, known as the "Newphase" alternator, an additional voltage control is incorporated which converts the alternator from a compensated machine to a closed loop system, with a positive voltage reference, against which the output voltage can be compared. This control system has three main parts : first, an error-detecting device ; secondly, an amplifier for magnifying the power of the

error signal, and, thirdly, a control arrangement connected in the main excitation circuit.

The first part utilises a cold-cathode discharge tube as the non-linear element of a four-arm bridge, which is fed from the rectified output voltage of the alternator via an auto transformer. The output of this bridge is fed to the control winding of a magnetic amplifier, which forms the second stage of the circuit. The power gain by this amplifier is in the region of 5000 : 1. Finally, the output of the magnetic amplifier is rectified and the voltage so obtained is used to feed the control winding of the saturable reactor connected in the primary circuit of the voltage transformer.

Whilst the excitation adjustment for phase changes is still brought about by the combination of the voltage and current transformer incorporated in all "Stamford" machines, any departure from the nominal voltage due to other causes is automatically corrected to within close limits by this overriding control.

It is stated that voltage recovery is very rapid and that, for example, full recovery can be obtained within 5 to 10 cycles of switching-on full load at lagging power factors. Similarly, because of linearity in the current transformer, good voltage regulation is possible on heavy overloads. The maker states that, with three or four times full-load current the voltage normally does not drop by more than 5 per cent

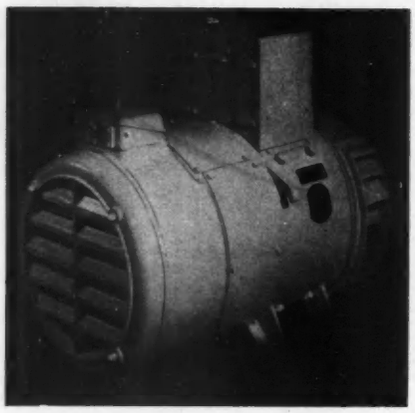


Fig. 3—"Newphase" alternator with voltage regulation control system mounted in ventilated casing on the machine frame—Arthur Lyon

in the "Newphase" machine, compared with 10 per cent in the standard machine. All the components of the additional control unit for the "Newphase" machine are housed in a casing mounted on alternator frame as illustrated in Fig. 3, making the machine self-contained.

Both standard and "Newphase" motors are available in nine frame sizes, giving outputs ranging, typically, from 5kVA to 75kVA, three-phase, at 50 c/s and 1500 r.p.m.

Metropolitan-Vickers Electrical Company, Ltd.

A new activity on the part of Metropolitan-Vickers Electrical Company, Ltd., Trafford Park, Manchester, 17, is the development of "Magistor" static control systems. Basically, the "Magistor" system consists of a range of unit "bricks" which replace relays and contactors and can be built up into an overall scheme of control. The main components of each unit are magnetic amplifiers, magnetic core devices and transistors. The absence of moving parts makes these components more rapid in action and mechanically more reliable than conventional relays and contactors.

The equipment shown by the company to typify this class of product is a photo-transistor relay consisting of two units of small dimensions—a lamp box and a receiver. The lamp box contains a transformer supplying a pre-focused lamp, from which light passes through a lens to produce a parallel beam ; the light beam is directed to the receiver unit, where it is focused by a lens on to the photo-transistor. The output of the photo-transistor energises a Metropolitan-Vickers "Fluxetter" flux resetting magnetic

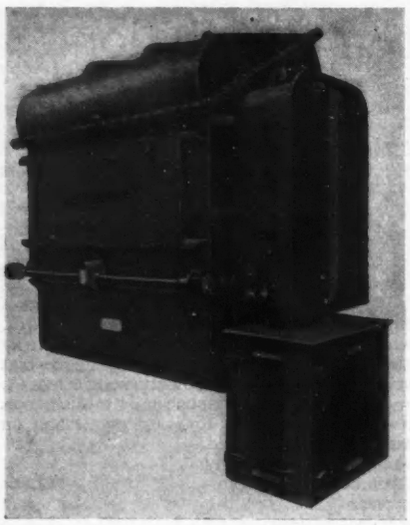


Fig. 4—On-load tap changer for use on transformers up to 66kV and with winding currents up to 800A—Metropolitan-Vickers

amplifier, which controls a relay having change-over contacts. The relay operates when the light beam is broken. This system dispenses with the need for thermionic valves, large photo-electric cells and h.t. supplies, and the simple circuit has printed wiring. The two units, the lamp box and the receiver, have the same dimensions—height 7⅞in, width 4½in, depth 3⅜in. The length of throw of light is 30ft maximum, or 25ft maximum when an infra-red filter is used. Typical applications are counting, level control, warning devices, height gauges, door control, smoke detection, inspection, edge position control, material handling, sequence checking and sorting.

Another exhibit to be seen on this stand will be the type "M" on-load tap-changer, which has been developed for use on transformers up to 66kV, and at the solidly earthed star point for voltage classes of up to 275kV, with winding currents of 800A. The tap-changer (Fig. 4) consists of twin selector switches per phase, diverter switches and transition resistors, operating mechanism and motor-driving gear. It is fully enclosed and bolted to a flange on the transformer tank ; usually the transformer and tap-changer are transported as a single unit. In operation, the main current is never interrupted during a tap change, and once a tap change has been initiated, it is impossible for the operator to interrupt it. Resistor transition ensures minimum arcing at the diverter switches.

The company will also show a number of motors, including a totally-enclosed d.c. motor of 60 h.p., 1340 r.p.m., with closed-air-circuit cooling. A single radiator of a new design is fitted on top of the motor yoke and air is circulated through independent internal and external ducts by means of separate fans fitted at the driving end of the machine. Cartridge-type bearing housings facilitate maintenance ; the machine can be dismantled completely without disturbing the bearings or exposing them to dirt.

The company will also show one of a new range of its "KN-C" squirrel-cage induction motors, following the introduction of the draft B.S. CW (ELE) 6246, which deals with the standardisation of ventilated motors. In outputs, dimensions and insulation (class E) all these motors conform with the new draft specification. Visitors to this stand will also be able to see the development model of a brushless, spherical induction motor which is being investigated in collaboration with Dr. F. C. Williams, Professor of Electrical Engineering at the University of Manchester. The machine is designed to give infinitely variable speed by varying the angle between the stator field and the direction of rotation of the rotor.

Asea Electric, Ltd.

A flash welder (Fig. 5) designed for tube systems up to 5½in outside diameter and equipped with an automatic flash and upset reduction device, will be shown by Asea Electric, Ltd., Walthamstow, London, E.17. This machine is rated at 150kVA at 50 per cent duty cycle rating, maximum welding input 346kVA, minimum 41kVA, and has twenty steps for current regulation. It is designed for a maximum upset pressure of 12 tons and a maximum clamping pressure of 12 tons. It will be seen from the illustration that the machine is designed with a flat top and horizontal tube clamping arrangement to suit the assembly of boiler elements, for example. The internal flash and upset reduction device operates automatically during the weld period.

This company will also show an "XAB 238" extra heavy-duty arrester (Fig. 6), which has a voltage rating of 238kV and is suitable for use on a 275kV solidly earthed neutral system. A zig-zag arrangement of the active elements within the sealed porcelain housing reduces the

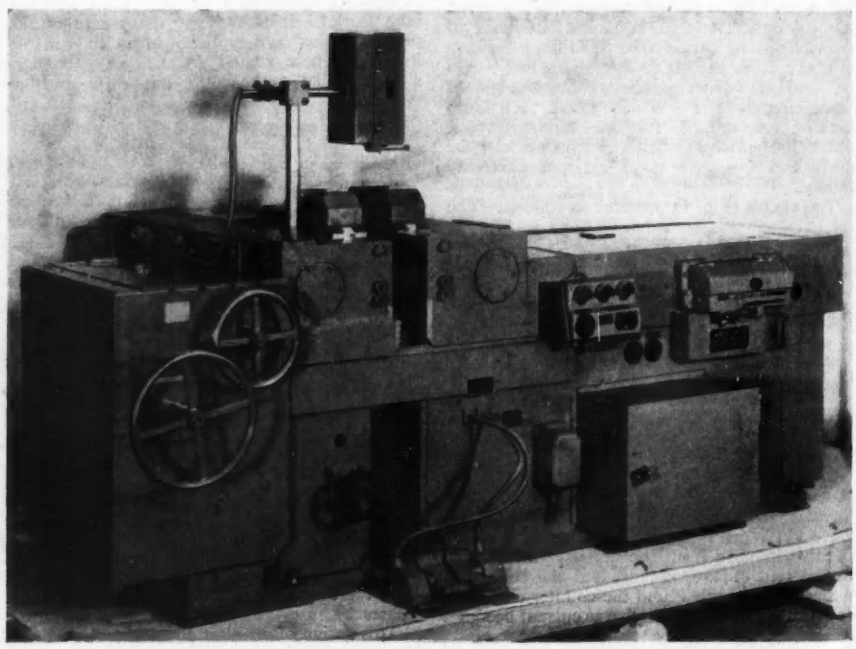


Fig. 5—Automatic flash welder for tube systems up to 5½in outside diameter—Asea

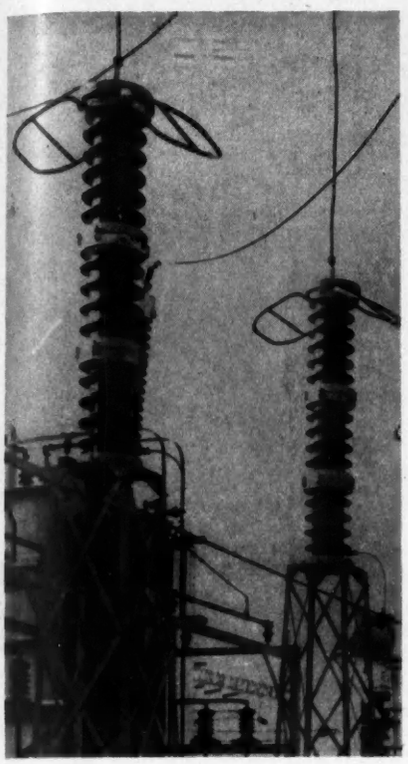


Fig. 6—Lightning arrester for a 275kV solidly-earthed system—Asea

overall height to 10ft 6in and the arrester is self-supporting. Pre-ionised spark gaps ensure constancy of sparkover voltage, whilst resistive and capacitive voltage grading of the spark gaps ensure close agreement between wet and dry sparkover voltages. The non-linear resistors in series with the spark gaps are chosen to give low residual voltages, even with heavy discharge currents, and at the same time to limit power-frequency follow currents to values that can be easily interrupted by the spark gaps.

Other exhibits on this stand will include an electronic metal detector "Asdet," for detecting metals or metallic ores generally, when distributed among non-materials ranging from minerals to foodstuffs, on conveyor belts or chutes. The "Asdet" equipment uses a search head consisting of a single coil as distinct from the conventional twin coil (balanced) system. It incorporates only three valves and has a considerable sensitivity range. It is equipped with an adjustable time-delay relay with two normally-closed and two normally-open contacts for signalling.

Two shunt-wound a.c. commutator motors for infinitely variable speeds will be demonstrated, with control gear. One motor has a speed range of 0/3000 r.p.m., rated 0/1 h.p., and the brushgear is remotely controlled by means of Bowden cables. The other has a speed range of 375/1500 r.p.m., 3/15 h.p., fully automatic brushgear, and is fitted with a differential limit switch enabling the motor preset speed to be adjusted from a remote position by the simple manipulation of a hand-wheel.

General Electric Company, Ltd.

A model of the nuclear power station which is to be built for the South of Scotland Electricity Board will be displayed by The General Electric Company, Ltd.

The company will also show its motor control centre (Fig. 7) which has been developed to provide a centralised control of a number of a.c. motors or circuits. The control centre is essentially a cubicle which will accommodate a wide range of starters and switch fuses for operation up to 600V. The individual control units are built to plug into the cubicle so that not only is the maintenance simplified, but units of the same rating may be easily interchanged. Any number of cubicles may be coupled together to form a compact switchboard. The complete equipment is generally in accordance with the requirements of specification I.C.I.–1954 of the National Electrical Manufacturers' Association of the U.S.A.

A new range of direct-to-line motor starters will also be shown. There are three series of these starters available, and they cover motors up to 7 h.p., from 10 to 12½ h.p. and from 15 to 30 h.p., respectively. These starters can be supplied with or without interrupter switches which are capable of breaking a stalled motor current up to ten times full load current.

A separate display, emphasising the requirements of the Clean Air Act, will include a photo-electric smoke density monitor. With this equipment in operation on any fuel-burning installation, the stoker is given a continuous indication of the smoke emitted from the stack. Facilities are provided for giving a warning or for operating damping equipment in the event of the smoke density exceeding a chosen limit amount.

Brookhirst Switchgear, Ltd.

A new form of cubicle switchboard designed for flexibility and accessibility will be shown by Brookhirst Switchgear, Ltd., Chester. In this class of switchgear the pillar type cubicle units are fabricated from heavy gauge sheet steel, each unit accommodating a top-mounted busbar chamber, vertical riser bars, and tiers of contactor starting equipments of various kinds, covering a wide range of ratings. Distribution gear can be included and, because of complete standardisation, subsequent interchangeability of units or additions can be easily effected on site. An interesting development in this design of switchboard is that the control gear is mounted on the inside of its compartment door, so that it swings out for inspection when the door is opened (Fig. 8). Lift-off doors are fitted permitting a complete starter unit to be quickly removed for servicing or replacement. Plug-in isolating contacts are employed for incoming and outgoing (and sequence) connections, thus dispensing with trailing cables. Besides the normal electrical interlock, each cubicle door handle is mechanically interlocked with the contactor to ensure that the contactor is opened before the door can be unfastened. Special attention has been given to short-circuit protection. Tests up to 35MVA fault capacity have been carried out and h.r.c. fuses are fitted immediately next to the isolating contacts. Control, metering and indicating devices are mounted on the front of the panels.

Another interesting exhibit will be a demonstration panel illustrating the application of static relay control (eliminating auxiliary switches from control circuits) to industrial equipment.

(To be continued)

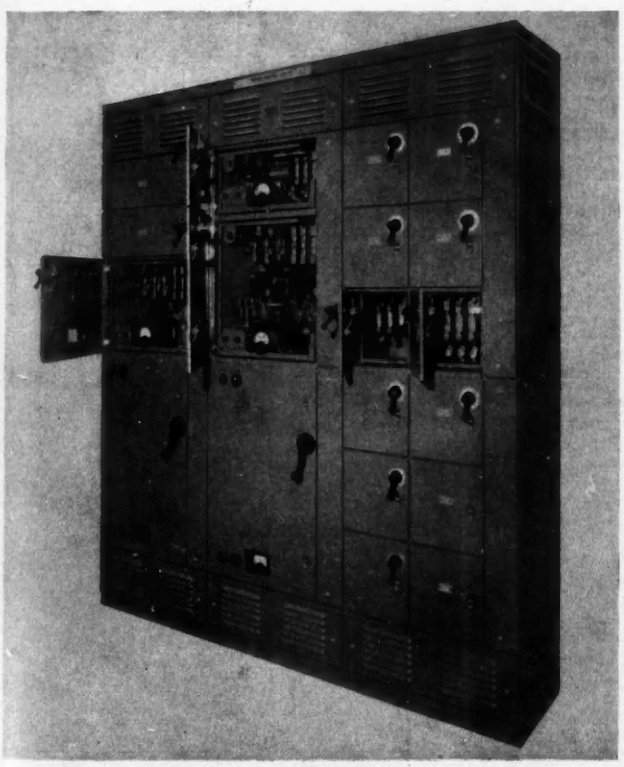


Fig. 7—Motor control centre for the grouped control of a number of a.c. motors or circuits—G.E.C.

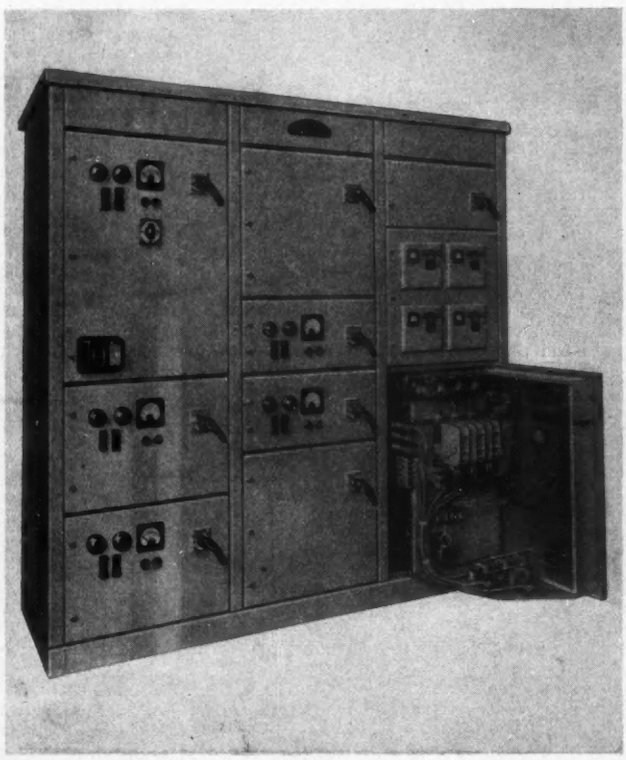


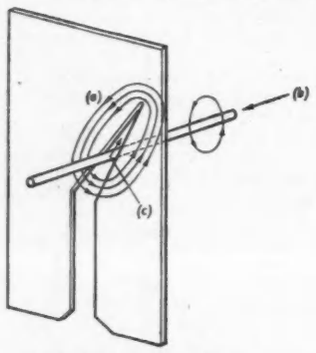
Fig. 8—Cubicle switchboard with apparatus mounted on hinged swing-out doors—Brookhirst

11kV Air-break Switchgear

THERE has been growing interest recently in this country in the use of air-break switchgear for voltages greater than 3·3kV, and it has led to the study and development of an arc-chute whose magnetic circuit is energised directly by the arc itself instead of by one or more coils switched in series with it. Simultaneously, with the prospect of oilless circuit breakers for such voltages, research has been undertaken to develop cast-resin insulants suitable both mechanically and electrically for the primary insulation of the fixed part of the panels which would be of a standard at least equal to that of the conventional insulants such as compound and oil. This work by A. Reyrolle and Co., Ltd., has resulted in the production of an 11kV, 500MVA resin-insulated air-break panel (Fig. 4) which has recently been successfully tested for short-circuit performance to the requirements of A.S.T.A.

The dimensions of the unit are 7ft 6in high, 2ft 9in wide, 7ft 1in deep, with a minimum wall-to-wall requirement of 15ft. The normal current ratings are 800A and 2000A and the busbars, which are of the continuation type, may have a rating of 2400A. The insulation of the fixed portion is epoxy resin, and joints are insulated with a filled polyester resin in such a way that if necessary they may be broken down and remade on site.

The current-transformer orifice insulator primary is cast as one unit (Fig. 2) and it is provided with a small platform on which the current-transformer cores and secondaries are mounted. These items are positioned by a brass tube fitted concentrically with the primary conductor and provided with a fixed clearance to the primary insulation so that discharge at working voltages is obviated. The cast-resin voltage transformer is plugged into a set of orifice insulators above the current-transformer chamber, and is horizontally withdrawable on its own trolley. Access is obtained from the back and, in the withdrawn position, the voltage transformer can be rotated about a vertical axis to permit the fuses which are housed within its plugs to be changed.



(a) Lines of magnetic flux in the iron.
(b) Direction of current flow.
(c) Direction of the force on the arc column

Fig. 1—The effect of an iron sucker plate on the arc column in the 11kV air-break circuit breaker

The front of the cubicle shown in Fig. 4 is 6ft 7in high, but this dimension can be increased when instruments and relays are required to be mounted on the panel. The compartment with the control handle houses a large terminal board, fuses and the racking-gear for the secondary-circuit isolating contacts, which are capable of being connected with the circuit breaker in the isolated position.

The circuit-breaker insulators, including the driving links, are of cast-resin and the fact that the casting process facilitates the manufacture of a cranked bushing has been used to provide an integral earthing facility. The main circuit-breaker contacts are mounted on "plant-pot" insulators into which are fitted cranked insulated connectors (Fig. 3) with cluster type isolating contacts fitted to both ends. These cranked bushings may be rotated through 180 deg., which permits the circuit breaker to be plugged into any of three positions, normal circuit, feeder earth, or busbar earth: the three positions are, of course, suitably interlocked and label indication is brought forward to the front of the panel.

As already mentioned, the arc-chutes of the circuit breaker do not require coils to energise an external iron circuit to produce the flux necessary to drive the arc into the chute. Instead, sandwich type arc-chute plates are used, in which an iron sucker-loop is moulded between plates of refractory material (Fig. 1). This device eliminates the need for an external magnetic circuit; furthermore, the time required for the arc to switch-in the coils is avoided, since the arc itself now produces the flux. In addition the arc-chute is so constructed that the arc moves initially in a very restricted tunnel, which means that arc movement in the lower part of the chute is under complete control and, consequently, the arc is prevented from moving down the chute without re-establishing itself upon the arc runners. Consistent performance is obtained in this way. The arc-chute plates are slotted, the slots being inclined to alternate directions throughout the arc-chute. As the arc rises in the chute the slots force the arc column into a zig-zag path of ever-increasing length until the top of the slots is reached, when further bowing of the arc takes place between adjacent arc-chute plates beyond the ends of the slots (Fig. 5). The top part of the arc-chute consists of a series of plates arranged to prevent the arc from

Fig. 4—11kV, 500MVA Reyrolle air-break circuit breaker with arc-chutes raised and side sheet removed to show contacts

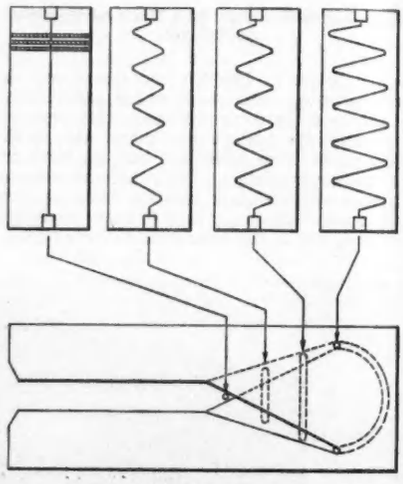


Fig. 5—Diagram illustrating how the arc column is lengthened in the slots in the 11kV air-break circuit breaker

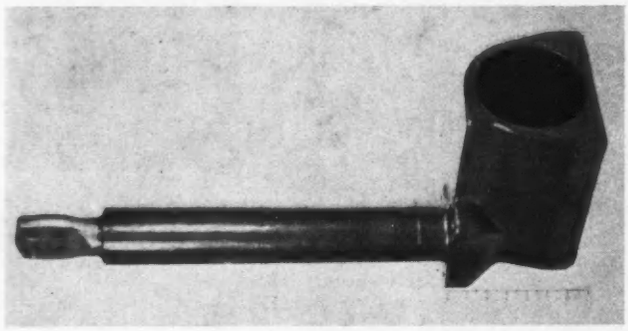


Fig. 2—Current transformer orifice insulator and primary stem of 11kV, 500MVA air-break circuit breaker

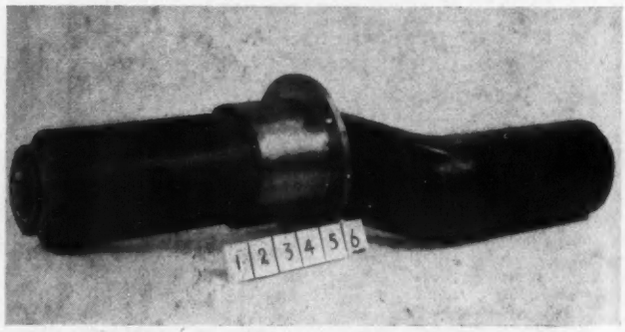


Fig. 3—Cranked circuit breaker bushing of 11kV 500MVA air-break circuit breaker

moving out of the top of the arc-chute and to cool and deionise the arc gases.

The maker states that the use of iron as an integral part of the chute does not make the weight of the chute prohibitive, because of, first, the relatively small amount of iron used compared with the external iron circuits and, second, the density and quantity of refractory material which in any event has to be used. The arc-chutes do require special handling facilities, however, but this problem has been overcome by using the normal racking-gear of the circuit breaker to tilt the arc-chutes for maintenance inspection and for replacement of plates if that should ever be necessary.

The circuit breaker is closed by a solenoid mechanism and opened by springs, both the opening and closing operations being controlled at the end of the stroke by oil dashpots. The speed of break, which is of considerable importance, since a slow speed of break may result in unnecessary arcing at the bottom of the chute, is about 15ft per second measured at the arcing

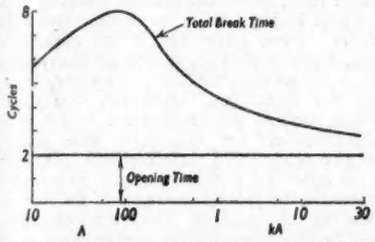


Fig. 6—Typical arc duration/breaking current curve of 11kV, 500MVA air-break circuit breaker

tip at the time of contact separation. The opening springs also drive two pistons which deliver air to three nozzles situated below the fixed main contacts. The air puffs so produced move low-current arcs into the chute more rapidly than they would move under their own self-induced driving forces. A graph of the way arcing time varies with current is shown in Fig. 6. When interrupting the higher short-circuit currents the arcing times are less than 1 cycle and for currents from 2½ to 100 per cent of the short-circuit rating arc extinction occurs within 5 cycles of initiation of tripping. Typical oscillograms of 100 per cent break duties are shown in Fig. 7.

We learn that high-speed photography played an important part in the development of this design of air-break circuit breaker. In the early stages of the development experimental arc-chutes were built with sides of transparent material, so that the behaviour of the arc could be recorded by high-speed photography. In this way visual information was obtained to supplement the results of oscillographic records of current and voltage and so give a better understanding of what happens in an arc-chute during a clearance and during a failure shot. In later stages of the development the same photographic techniques enabled incipient faults to be recognised and remedied, and thereby helped to establish consistency of performance in the finished product.

Skelp Mill at Newcastle, N.S.W.

FOLLOWING the completion a few months ago of the hot strip mill at the Australian iron and steel industry's plant at Port Kembla, in New South Wales, priority in the current post-war expansion of the Australian steel industry is now being given to two items: the erection of a new blast-furnace at Port Kembla, at a cost of £9,000,000, and with an putput expected to average over 600,000 tons of pig iron per annum, and the building of a new 18in strip and skelp mill at the steel works at Newcastle of the parent company, the Broken Hill Proprietary Company. Priority has been given to this type of mill to meet the growing demand for continuous weld pipe and cold roller strip—a demand that is taxing the capacity of the existing 10in mill at Newcastle which rolls feed for this class of product. In addition to restriction in tonnage, the maximum width that can be rolled in the existing mill falls short of that required for a considerable number of applications. The existing 10in mill occupies a great deal of its time in producing skelp and the demand for this commodity prevents the merchant finishing section of the mill being used to capacity. The transfer of skelp to the new mill will allow the existing 10in mill to be used exclusively as a merchant bar mill, thereby contributing very markedly towards the elimination of present shortages of merchant bar. At the present time the capacity of the open hearth to produce ingots, and of the bloom and continuous mills to convert these ingots into semi-finished products is beginning to outstrip the capacity of the secondary mills to absorb the resultant billets and slabs. Installation of the new skelp and narrow strip mill will take care of this situation, and will provide some reserve finishing mill capacity for the future.

The new mill will consist of nine horizontal stands with rolls ranging in diameter from 17¾in to 20¾in, with a maximum finishing speed of 2000ft per minute. Five vertical edging mills will also be included to ensure correct width control and the proper edge development required for skelp products. Provision has been made for the installation of a tenth horizontal stand which, when installed, would be located between the present first stand and the reheating furnaces. The purpose of this tenth stand is to increase still further the capacity of the mill if it should be needed in the future, or, alternatively, to facilitate the production of merchant bar, which could also be rolled on this mill should the future development of the industry require it. Flat products are diverted away from the main centreline of the mill. This is to allow for the future installation of a run-out table and the hot beds that would be associated with merchant bar production. Initially, the mill will roll coiled flat product from 3in to 16in in width and ranging down to 0·070in thickness in the narrowest width. The building to house this initial installation is 80ft wide and 600ft long, whilst the billet yard feeding the furnace has a 90ft span and is 575ft long. Service is provided by a 25-ton crane in the billet yard and by 25-ton and 10-ton cranes in the mill building itself.

Many of the features of the mill are new to Australian smaller mill practice. All slab handling in the billet yard will be by means of magnets, 8ft wide. This will permit the slabs being off-loaded from the trucks in single tiers extending over the full width of the truck. Mechanical charging skids will separate and align slabs and deposit them individually on the furnace charging conveyor. There is a departure from the traditional 30ft length of billet: the furnace has been designed to accommodate 32ft lengths. Mill motor power is supplied from rectifiers instead of motor generator sets. There are individual drives for every roll stand and a rotary cobble shear at about the mid-point of the mill. In the event of a cobble at the finishing end of the mill the oncoming slab can be cut to a scrap pan length by the rotary shear. Other new features include power-operated screw downs on the last five horizontal stands; mechanical cross-transversing of the last five horizontal stands, and automatic speed compensation to avoid stretching between stands. This project reflects the latest thoughts in design for this type of mill.

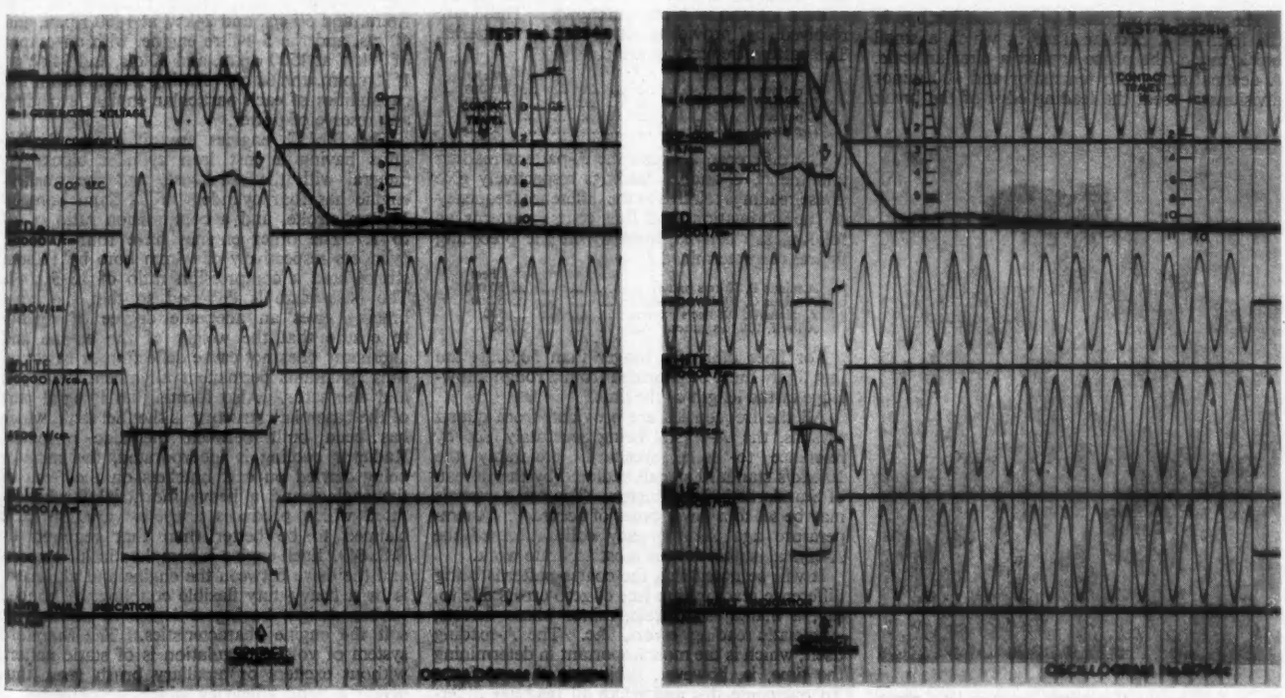


Fig. 7—(Left) Oscillogram of 100 per cent symmetrical duty 500MVA at 11kV. (Right) Oscillogram of 100 per cent asymmetrical duty 500MVA at 11kV

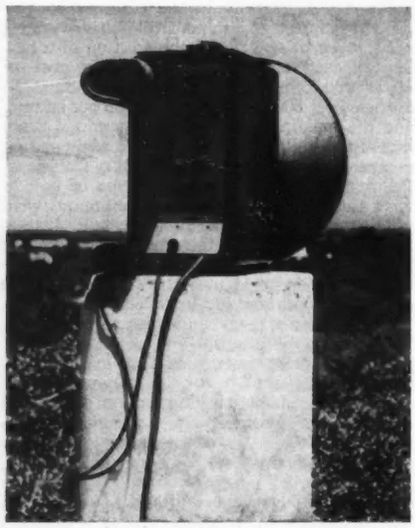
Surveying Instrument for the Precise Measurement of Length

WE recently attended a demonstration of an instrument intended for the precise measurement of distances. Its practical range is about 35 miles, and the probable error of measurement is given as 1 part in 300,000 ±2in. The instrument transmits, from a master station set up at one end of the line to be measured, a modulated radio wave of 10cm wavelength (3000 Mc/s). This wave is picked up at a remote station set up at the far end of the line, and re-radiated back to the master station. At the master station, the phase shift of the modulated wave is measured; by successive measurements of the phase shifts of different " pattern frequencies " superimposed on the carrier wave, the length can be computed. The instrument, which is shown in the accompanying illustrations, has been named the " Tellurometer," and has been developed by Mr. T. L. Wadley, of the South African Telecommunications Research Laboratory. It is to be introduced into this country by Cooke, Troughton and Simms, Ltd., in conjunction with Tellurometer (Pty.). Ltd., of Cape Town.

It will be appreciated from the foregoing remarks that the " Tellurometer " is likely to become one of the fundamental instruments of the geodetic surveyor's equipment, since it enables rapid measurement of, for instance, a base line, which might take several weeks to measure by conventional methods. The principle of using the velocity of light as the basis of measurement is not entirely novel, and an instrument known as the geodimeter has been developed using modulated light waves. It was considered, however, that there would be advantages in using radio micro-waves, and hence the present instrument was devised. Without attempting to explain the electrical principles on which the instrument is based, it can be stated that the modulated wave is received at the remote station, and is, in effect, re-radiated from the transmitting system of that station ; the re-radiated wave is a similar wave of more complex modulation which effectively retransmits the " pattern "frequency modulation, re-radiation being instantaneous. The instrument indicates the phase shift between the outgoing and incoming modulations, the comparison referring to the focus of the mirror.

The phase is indicated on an oscilloscope in the form of a circular trace in which a small break marks the phase against a circular scale. A decimal scale with ten major and 100 minor divisions is used, the leading edge of the break in a clockwise sense being read usually to the nearest minor division or at short ranges to perhaps half or even quarter divisions. With a pattern frequency of 10 Mc/s a complete rotation of the phase indication represents a change of one-tenth of a microsecond in the transit time over the double path. Each minor scale division thus represents 1 millimicrosecond and is equivalent to just under 6in, a complete rotation of phase being equal to approximately 50ft.

The 10 Mc/s pattern, or A-pattern phase as it is usually referred to, thus indicates the final two figures in the transit time in millimicroseconds,



Readings are taken at the " master " station from a circular scale which is viewed through the eyeshade at the top of the instrument. A routine of reading is followed to correct for various errors such as those due to weather conditions

the preceding figures or whole number of A-pattern rotations being unknown. These are resolved by providing three further patterns. The pattern frequencies are :

	Mc/s
A pattern	10·000
B pattern	9·990
C pattern	9·900
D pattern	9·000

The difference between the A-pattern reading and the B, C and D readings respectively give phase readings relative to the difference frequency of the modulations and thus coarse patterns, as follows, are derived, from which the preceding figures are determined :

	Feet
A minus B, 10 kc/s pattern	50,000
A minus C, 100 kc/s pattern	5,000
A minus D, 1000 kc/s pattern	500
A itself, 10 Mc/s pattern	50

For lines of length longer than 50,000ft the first figure must be provided from a rough knowledge of the length of the line.

All the frequencies are provided from quartz crystals, the A-crystal being accurately set by reference to some standard, preferably the 10 Mc/s standard signals radiated by the Bureau of Standards in Washington. The other crystals may be set to a lower order of accuracy. A temperature against frequency calibration of the A-crystal is used for the most accurate work.

It will be noted that the coarse patterns being difference readings are free of zero errors due to, say, a maladjusted scale, minor phase defects, systematic reading errors, &c. The A-reading itself, which is the most important in determining the time, is, however, subject to these defects. To overcome this and make all readings differences, a so-called negative A-reading is made. This may be treated as arising from a pattern frequency of minus 10 Mc/s. That is to say, the reading when subtracted from the +A reading gives a 20 Mc/s pattern free of all internal instrumental error, personal error, &c. The −A reading rotates backwards relative to the clockwise increase of the positive patterns as the instruments are moved further apart. The display is still in the same sense and is read in the same manner, the reversal being in the fundamental physical process, not the indicating circuits. The same 10 Mc/s crystal is retained at the master station, the operation being controlled by the remote operator only.

In addition to the above, a simple reversal of phase provides reverse indications on both the +A and −A readings and, by averaging, any centring error in the display is eliminated. This function is also under the control of the remote operator only, the master observer retaining the 10 Mc/s pattern as before.

Another source of error arises from propagation effect, due to stray reflections from objects of the microwave beam, and, of course, from the ground itself, as the beam being relatively wide, i.e. about 10 deg., cannot be elevated free of the ground. These errors are, in the majority of cases, almost negligible, as most ground surfaces diffuse the ground reflection sufficiently to leave only the direct ray. However, occasionally ground surfaces are encountered which reflect quite effectively and, in general, water surfaces will give pronounced surface effects. On paths of the order of 20 miles in length, little error is involved if the ground clearance of the ray path is less than about 200ft. The error will in either sense be dependent on the relative phase of the carriers and will assume all values around the true value as the carrier phase is changed. So, as a matter of routine, all measurements are made on a series of carrier frequencies spaced perhaps 10 Mc/s apart, the difference in the ray paths causing the indirect carrier to assume all values of phase relative to the direct ray.

The " Tellurometer " measures distances by a phase-shifting procedure on modulated 10cm radio waves. A " master " and " remote " instrument are used

Standard Range of Generating Sets

A NEW standard range of generating sets incorporating Newage/B.M.C. diesel engines, of 2·2, 3·4 and 5·1 litres capacity, coupled to a " Stamford " alternator, is being produced by Newage (Manchester), Ltd., of 6, Carlos Place, Grosvenor Square, London, W.1. The range consists of three basic models—the 2·2-litre engine, with an output of 10/12kW at 1500 r.p.m. and 50 c/s, and 14kW at 1800 r.p.m. and 60 c/s ; the 3·4-litre engine, giving 15/20kW at 1500 r.p.m. and 50 c/s, and 24kW at 1800 r.p.m. and 60 c/s, and the 5·1-litre engine, with an output of 30kW at 1500 r.p.m. and 50 c/s, and 34kW at 1800 r.p.m. and 60 c/s. Rating is well within the capabilities of each particular engine, excluding any reserve of power.

The B.M.C. engines are all overhead-valve units having a cast iron cylinder block cast integral with the crankcase, and the smallest engine has four cylinders of 82·5mm bore by 101mm stroke, and a compression ratio of 20 to 1. The other engines have four and six cylinders respectively of 95mm bore by 120mm stroke, and a compression ratio of 16·5 to 1. The base plate is designed so that the cross bracing gives an adequate degree of rigidity to ensure that the weight of the engine and alternator does not cause deflection or twist and thus maintains permanent alignment of engine and alternator. Also forming an integral part of the base plate structure is the fuel tank, which has been built between the side members. Radiator cooling is incorporated, the radiator being carried on cast brackets on the front of the engine, and a heavy industrial flywheel is fitted which produces a cyclic variation ratio claimed to be better than that required by B.S. 649. Each engine is complete in all respects and the drive between the engine and alternator is by a heavy-duty flexible coupling, of bonded rubber design, having a degree of stiffness to suit the engine characteristics. The Stamford system of voltage regulation is of static pattern without exciters or auxiliary brush gear, thus giving a good efficiency which, combined with the low fuel consumption of the engines, is claimed to ensure low running costs.

Repetitive Inflation of Tubeless Tyres

THE tubeless tyre presents a problem in its initial inflation : air cannot be delivered through the valve fast enough to expand the beads on to the rim, and it is necessary to obtain a seal by tightening a strap or tourniquet around the periphery of the tyre. This is an unduly costly process for use at the frequencies required by a motor manufacturer, and for large outputs there is used an alternative process which is, in effect, to lower suddenly the pressure outside the tyre. This is done by clamping the wheel and tyre between two circular platens which seal on the side walls of the tyre, and raising the pressure in the enclosed space ; the air is then exhausted more rapidly than it can pass out past the tyre beads, and the tyre snaps into place on the rim. It was at first believed that the abrupt impact of the bead was essential to effect a tenacious seal and tyres were inflated to pressures as high as 100 lb per square inch, the excess being exhausted through the valve. After eighteen months' use of tubeless tyres, however, the Austin Motor Company believes that it is satisfactory to inflate the tyre to no more than running pressure. The latest machines to be employed by it are automatic from the time a wheel is laid on the intake conveyor, and have also been improved in that the release of the pressure outside the tyre is made through a valve, and not by parting the platens. This latter change has put an end to the explosive noise that accompanied the process, although there is still a considerable release of energy when the platens open because they seal by squeezing the empty tyre.

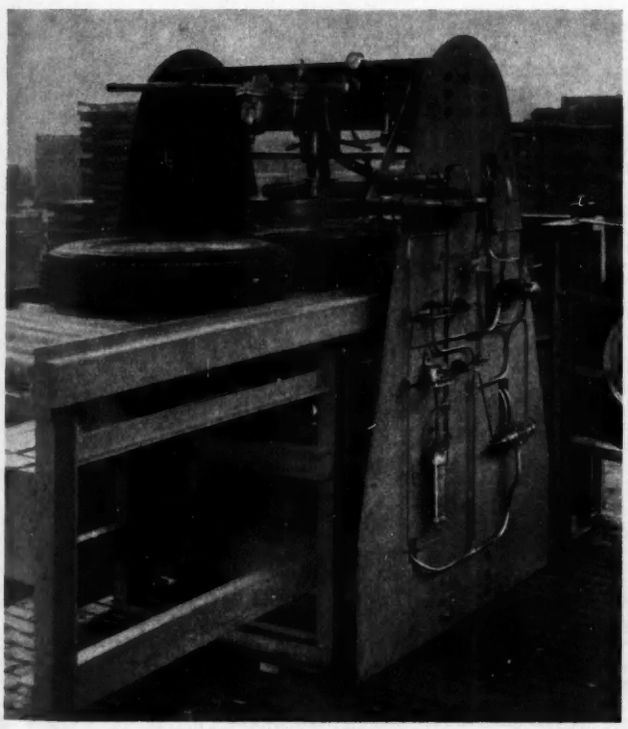
The new machines, seen in the accompanying illustrations, were built by Weldall and Assembly, Ltd., Stourbridge, Worcs, on the principles established by the Dunlop Rubber Company. When a tyre is laid upon the conveyor, the power-driven rollers carry it forward and it drives the previous tyre into the machine; when that tyre is in position a switch reverses the rollers temporarily to carry the wheel we are following clear of that preceding. When the machine is empty, the tyre is in its turn pushed in until it contacts a gate across the machine bed, when it is located between rollers at each side. The platen below the wheel is then driven up by a large pneumatic ram actuating a toggle linkage, and forced against the top platen. Provided the previous wheel has cleared the machine, the space between the platens is then pressurised ; when the pressure reaches a value set in the unloading valve, seen in the centre of the side plate at wheel height, the supply of air is cut off and the space opened to atmosphere by the large changeover valve connected to the top platen by a flexible hose. At this stage a long-stroke ram commences to fill through a calibrated orifice ; when this ram is fully extended it operates a valve to separate the platens by reversing the large ram and breaking the over-centre linkage. The wheel is then pushed under the open gate by the following assembly, and moves on to a continuously running conveyor rather faster than the loading conveyor. When it touches a switch at the far end of a tilting table, the table is lowered into the vertical plane and the wheel rolls away down a chute ; as it does so it depresses a trip in the floor of the chute which causes the table to rise, whereupon the next wheel is inflated. This interlock causes the machine to stop at the stage of lifting the wheel if the delivery channel has been allowed to fill.

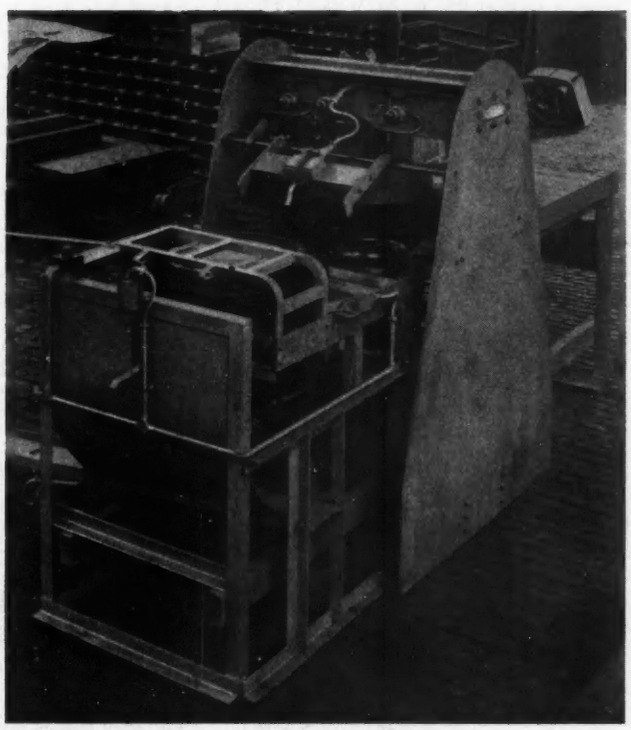
An advantage of lifting the wheel bodily is that the two platens can be bulged to occupy part of the hollow within the wheel, and thereby economise on air. The lower platen has a rubber ring, and the upper a metal rim, to seal against the tyre ; the presence of the makers' name and other embossed characters does not spoil the seal. The air, both for the servo system and for inflation, is infused with oil by a Norgren dispenser in order to secure reliable valve actuation ; separate reducing valves are provided for the operating and inflating systems. Because the fluctuating demand, a large air reservoir near to the machine is needed. The process of seating the beads costs the tyre some pressure, so that to obtain 26 lb per square inch in the assembly the unloading valve is set at 30 lb per square inch ; the required pressure is maintained within a variation of 2 lb per square inch. The throughput if the conveyor is kept loaded is about six wheels a minute. Different rim widths can be accommodated by adjusting the height of the top platen. It should be noted that the right-hand illustration shows an early machine with the changeover valve inside the side plate ; the later machines are as seen at the left, and have a casing over the control gear, which is supplied by the Lang Pneumatic Company.

Carbide Tool for High Tensile Metals

THE machining of very high tensile steels such as are being used to an ever increasing extent in the aircraft industry, presents tooling problems which have been the subject of much study at the College of Aeronautics, Cranfield. One of the results of these investigations has been the development of what is known as the " cross chord " form of turning tool and is now being made by the Production Tool Alloy Company, Ltd., Harlington Works, Sharpenhoe, Bedford. One of these tools can be seen in the illustration overleaf. It consists of a rectangular block of tungsten carbide $\frac{1}{4}$in by $\frac{1}{8}$in by $\frac{1}{16}$in thick, mechanically clamped by a carbide-faced high tensile bridgepiece in a rigid tool holder made of a tough grade of tungsten carbide. The block of carbide, or cutting tip, is precisely located on a lapped seating in the holder, in which it is set at a fixed angle of some 50 deg. to the axis of a bar being turned in a lathe. The block is also tilted in the seating at 6 deg. to 10 deg. to give a clearance on the finished diameter. The tool block cuts along the length of the $\frac{1}{4}$in edge and not on one point only. By turning and reversing the tip when an edge becomes blunt its four edges can be brought into service successively, without need for changing the tool setting or removing the holder.

The principle of the " cross chord " method of turning can be seen from the diagram we reproduce. In a section *AA* of the work, taken at an angle of 50 deg. to the axis of the bar, it will be seen that the cutting edge *CC* is along a chord

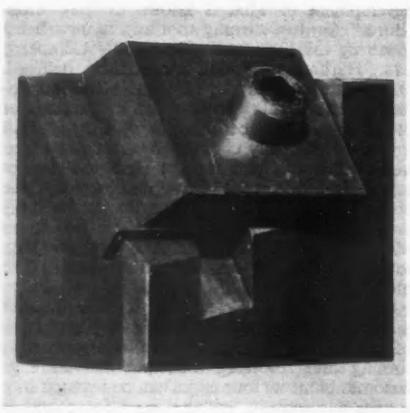




(Left) Input side of inflating machine, with tyres rolling away, in position, and on loading conveyor. At the top can be seen the air filter, oil dispenser and inflating reducing valve : prominent on the side plate are the change-over valve, unloading valve and, bottom left, the time delay ram. (Right) Output side, showing lower platen, stop gate and tilting table. The main closing ram can be seen low down inside the machine

of the greater ellipse corresponding to the section of the bar stock, and is also tangential to the minor ellipse, representing the turned bar. In a conventional bar-turning tool the cutting edge is arranged more nearly along a line normal to *CC* —that is along the minor axis *PR* of the elliptic sections. The geometry of the cutting edge is quite simple and shear planes in the chip are substantially flat, whereas a conventional tool has shear planes formed from a face and diameter together. Whilst these planes in a conventional tool are blended by the use of tool nose radii, interference takes place in the chip flow, particularly at high feed rates.

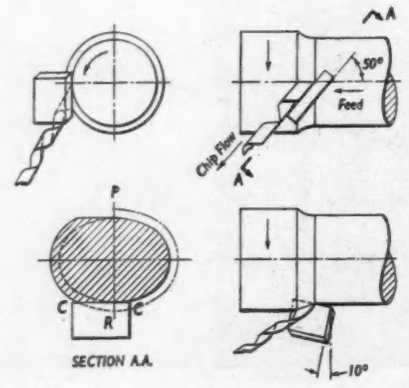
The new tools produce a wider yet thinner chip than standard tools but they take lighter cuts at very much higher speed and feed rates. The increased number of passes required to remove a given amount of metal with "Cross Chord" tools are more than counterbalanced by the higher speeds and feeds at which they operate. Tests are stated to have shown that floor-to-floor times with one of the new tools can be at least



"Cross Chord" tungsten carbide lathe tool with mechanically developed tool bit, the cutting edge of which is presented at an angle of 50 deg. to the axis of the work

50 per cent under those with a standard tool, whilst giving a considerably longer working life and a much higher standard of finish on high tensile alloy steels.

We were recently given an opportunity to attend a demonstration of the new tool at the laboratory of the College of Aeronautics. In the tests 80-ton alloy steel was turned at a cutting speed of 650ft per minute with a 0·030in depth of cut and a feed rate of 0·032in per revolution. For a second test on 120-ton alloy steel the feed rate was reduced to 0·030in per revolution and the depth of cut to 0·010in. In each case the quality of the surface finish was particularly high and the effective tool life was obviously much higher than that which would have been obtained with a conventional design of carbide tool.



Principle of "Cross Chord" bar turning tool. The diagram shows how the cutting edge, at an angle of 50 deg. and tilted at 6 deg. to 10 deg. for clearance, is presented to the bar

Mechanical Efficiency

We attended last month a series of observed trials held to elucidate the effect of Bardahl as a lubricant additive. (The applications of Bardahl were described in these columns on February 24, 1956, page 233.)

A number of vehicles, principally private cars, were the subject of the trials. Each was fitted with an auxiliary petrol tank having a narrow transparent filler spout, and driven a measured distance of eight miles at 30 m.p.h.: the route was free from traffic and obstructions, and called for torque in top gear ranging from large to negative. The petrol consumed was measured by refilling the tank from a graduated glass. Bardahl

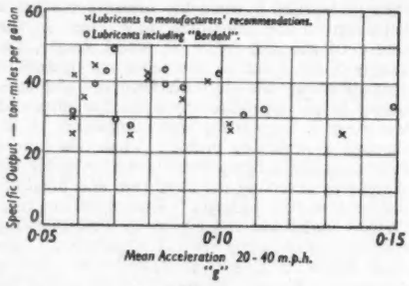


Fig. 1

was then added to the lubricant in the sump, gearbox, and differential case, and the vehicle driven a short distance to allow the additive, which is surface-active, to become effective. The initial test of fuel consumed over eight miles was then repeated: in each case the run included one full-throttle hill climb commenced at 30 m.p.h. and one trial of acceleration from 20 m.p.h. to 40 m.p.h.: the acceleration was inferred from the distance covered, not the time elapsed.

The accuracies to be expected may be estimated as about 1 per cent on consumption and within 20 per cent for acceleration. The results are given in the accompanying table, and show that the increased mechanical efficiency has a significant effect upon fuel consumption.

Although these results carry a large measure of random error, the driver, for instance, being different in each case, they have the merit of being taken at the same ambient pressure, temperature, and humidity. In view of the prevailing lack of dynamometer results, it is worth while to analyse these further. Some correlation of the widely varying specific output figures, which, it must be emphasised, are based upon an estimated load aboard each vehicle, can be obtained by plotting them on a base of acceleration as in Fig. 1. It appears that a large measure of torque in hand is accompanied by poor efficiency: the converse, however, is not necessarily true. Among the points which denote low acceleration and efficiency, however, are those of the Austin A.50: since this vehicle had not been run-in, these results may well be regarded as not comparable with the remainder.

A treatment which avoids the use of the acceleration figures, which are severely affected by speedometer errors, is presented in Fig. 2, showing the reciprocals of fuel consumption plotted against the distance travelled for unit cylinder volume swept: this plot is also attractive because it does not depend upon the weights of the vehicles. The significance of a linear relationship on such a graph is that, over the range concerned, the thermal efficiency of the engine varies directly with indicated mean effective pressure: since the engine is controlled by altering the volumetric efficiency, nothing more than an approach to linearity would be expected over such a wide variety of vehicles. However, it should be noted that the two points which lie far above the line were both established by engines of the same design—Triumph "T.R.2"—using twin carburetters, while in the other direction the A.50 result is again suspect.

It therefore appears that the volume swept per mile is a major parameter determining the fuel consumption of a vehicle of a given weight: if the percentage decrease in fuel consumption with the oil additive in use is plotted against this

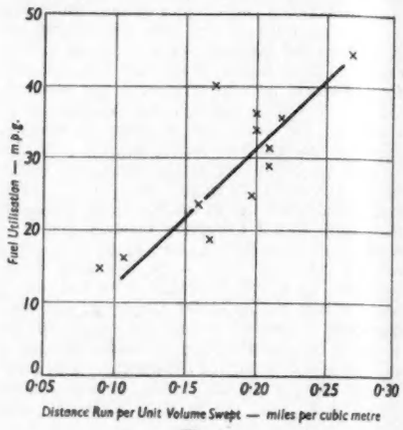


Fig. 2

parameter, it is not easy to draw a line through the points—as a difference of two figures, they naturally show a heavy scatter—but the improvement may be conservatively set at 3 per cent in the most heavily loaded engines and 15 per cent in the least.

While these effects would obviously diminish at higher outputs, it is nevertheless striking to note how low the mechanical efficiency may fall at low speeds: Bardahl is not claimed to reduce friction by more than 20 per cent, which, if true, would imply that mechanical efficiencies between 85 per cent and 25 per cent were prevailing.

Performance at 30 m.p.h.

Vehicle	Swept volume, c.c.	Distance per unit volume swept, miles per c.m.	Recommended lubricants			Bardahl additive		
			Petrol utilisation, m.p.g.	Specific output (approx.), ton-m.p.g.	Acceleration, *g*	Petrol utilisation, m.p.g.	Specific output (approx.), ton-m.p.g.	Acceleration, *g*
Jensen, 541	3993	0·0914	15·5	26	0·134	20·3	33	0·149
Alvis	2993	0·105	16	27	0·103	18·5	31	0·107
Triumph, T.R.2.	1991	0·17	40	42	0·079	41	43	0·084
Standard "Vanguard" (T.R.2.)	1991	0·151	29	40	0·096	30·5	42	0·099
Ford "Consul" Mk. II	1702	0·16	23·7	35	0·089	25·1	38	0·089
Austin, A.50	1489	0·168	19	25	0·074	21·5	28	0·074
Peugeot, 203	1290	0·2	36·1	41	0·079	35·1	39	0·084
Hillman "Husky"	1265	0·197	24·6	25	0·058	29·1	29	0·07
Austin, A.40	1200	0·199	34	45	0·064	37	49	0·069
Ford "Prefect"	1172	0·208	28·8	30	0·058	29·8	31	0·058
Ford "Anglia"	1172	0·208	31	28	0·102	36	32	0·112
Ford "Escort"	1172	0·215	35·2	36	0·061	37·8	39	0·064
Morris "Minor"	948	0·267	44·2	42	0·058	45·7	43	0·067

Small Centrifugal Pumps with Mechanical Shaft Seals.—A new range of centrifugal pumps, with five sizes of delivery connections from ¾in to 1½in., now being made by Girdlestone Pumps, Ltd., Woodbridge, Suffolk, is fitted with mechanical shaft seals. All five sizes of the pumps have the same shaft and flange dimensions to afford interchangeability of mounting. The seals are cooled by the liquid being pumped and can be easily replaced by removing the pump end cover and impeller. The pumps are available in cast iron, bronze or stainless steel to suit them for handling a variety of liquids. The type of material used for the mechanical seal is in accordance with the liquid handled: they are made with seats of cast iron, "Ni-resist," lead bronze, "Stellite" or ceramic material with rotating faces of carbon, "Lacrinite," or P.T.F.E.

Exhibition of the Physical Society

No. II—(*Concluded from page 495, March 29*)

THE 41st Physical Society Exhibition took place last week: we continue below an account of some of the exhibits.

An attractively simple computer giving the product of shaft speed and linear displacement was shown by Nash and Thompson, Ltd., Oakcroft Road, Chessington, Surrey. It is intended to be tough and reliable enough for engineering application and is essentially an a.c. tacho-generator in which, in the present version, the flux influencing the stator coils can be varied from zero to a predetermined maximum in accordance with one variable, the second variable being speed of rotation of the shaft.

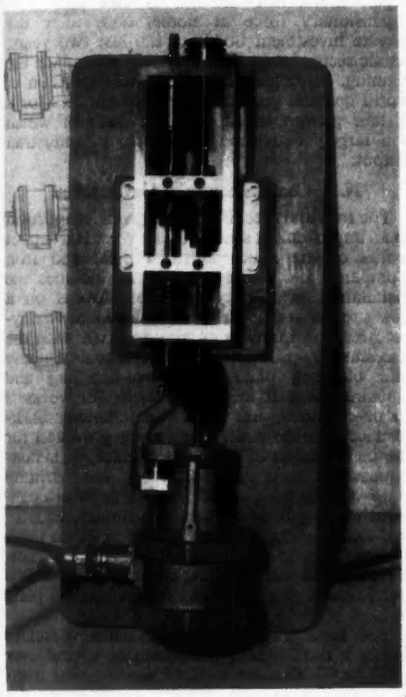


Fig. 7—An electro-mechanical computer which indicates a product of shaft speed and linear displacement is seen here applied to a dynamometer to indicate power

The computer will indicate on a meter the factor of revolutions per minute of the shaft and linear movement of the rotor with a sensitivity of 0·001 of either variable.

An electrical output proportional to these variables is obtained by a variation of flux caused by the position of the rotor relative to the stator. To obtain a variation of flux with a linearity of 0·5 per cent of either variable an "Alnico" rotor is designed and manufactured to rather more precise physical dimensions than is customary in magnet manufacture. A specially designed stator, of length exactly equal to the rotor, carrying a three-phase winding, is used and a dummy stator or keeper is mounted in tandem with it. This is so constructed as to abut the main stator laminations and also to shield the coil return loops projecting from it. The dummy stator has an overall length equal to that of the rotor magnet, which is mounted on the shaft so that it can move freely along it while rotating, from a position exactly beneath the keeper where the output will be zero, to a position directly beneath the stator where the output will be at its maximum.

The design is such that as the magnet is moved towards the active stator the flux influencing the coils is proportional to the displacement and thus the voltage generated is proportional to both speed and displacement. At constant speed a graph showing the relationship between voltage and displacement is linear and at constant displacement a graph showing voltage against speed is again linear, in both cases to within 0·5 per cent.

Fig. 7 shows the computer in use on a transmission dynamometer. The torque passing through the helical gears is translated into displacement by allowing one gear to move against a spring, and the speed is taken directly from the shaft. The power passing is then indicated directly.

The Research Laboratories of The General Electric Company, Ltd., showed switching devices which depend upon the electrostrictive deformation of ferro-electric ceramics under the action of an electric field. A thin strip of ceramic, in this case a form of barium titanate, is bonded to a thin strip of metal. When a voltage is applied across the faces of the ceramic strip the reaction of the resulting deformation on the metal backing causes the strip to bend in a manner analogous to the bending of a temperature-sensitive bimetallic strip. The movement resulting from the bending of the element is used to operate light contact assemblies.

These devices are compact and have the advantage of low power consumption compared with the magnetic relay. For example, after changing the capacitive impedance of the electrostrictive relay and thereby operating it, a negligible leakage current is dissipated in holding the relay operated. One relay demonstrated was a self-excited vibrator operating at a low frequency and using only a few milliwatts of power.

In Fig. 8 a relay assembly is seen beside a match. The electrostrictive ceramic is the white upper layer on the steel strip which carries the insulated contacts at its end.

Metropolitan-Vickers Electrical Company, Ltd., showed a mass spectrometer designed as a simple portable instrument for detecting extremely small concentrations of one gas in another; in addition to high sensitivity it gives a direct measure of concentration and is therefore positive in indication.

The mass spectrometer can be used for the testing of pressurised or evacuated systems; it will test for the presence or absence of leaks, measure the rate of leakage, and, if necessary, find the exact location of a leak.

With vacuum systems the instrument is connected to the system and the tracer gas is applied to the exterior either by probing or by placing an envelope or hood around the whole or part of the system. Pressure vessels and systems are tested by placing the tracer gas inside under pressure and sampling the atmosphere around suspected parts.

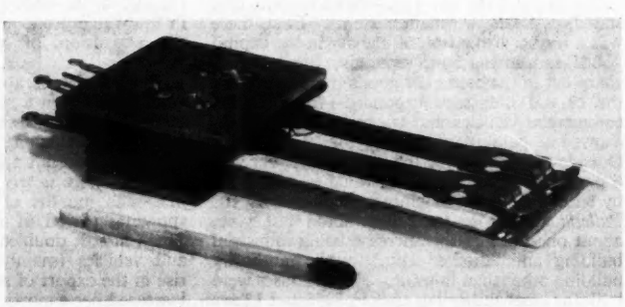


Fig. 8—A relay activated by electrostrictive deformation

The MS6L mass spectrometer is a self-contained unit. The lower half of the cubicle contains the analyser tube together with its associated magnet and vacuum system. The tube is a 90 deg., 10cm radius tube of all-metal construction, and provision is made for easy dismantling of the ion source for cleaning or filament replacement.

All switches and adjustments that are used during operation of the instrument are mounted on the sloping panel at the front of the drawer containing the electronic circuits.

The sensitivity is better than 1 in 200,000 parts for helium in air. For leaks in vacuum systems this gives a minimum detectable leak of the order of 5×10^{-7} lusec (litres at 10^{-6}mm Hg per second). Such a leak rate means that only one thirtieth of a cubic centimetre (at atmospheric pressure) would pass through in a year.

With a system pressurised with helium at 15 lb per square inch a leakage less than 10^{-6} cubic centimetre per second should be detected. Vessels which can withstand larger pressure differentials may with advantage use higher pressure, or alternatively economise in the use of helium by mixing it with air.

Another form of the MS6 mass spectrometer has been employed for the continuous monitoring of the composition of a process stream. In addition to the mass spectrometer there is a gas handling system enabling samples at approximately atmospheric pressure to be continuously admitted to the instrument; a programming unit controls the instrument so that the composition of individual components is recorded in turn, and, if necessary, switches from one sample stream to another in a predetermined sequence.

Dry Powder Fire Extinguisher

A DRY powder fire extinguisher which is capable of smothering a fire within a few seconds has been produced by Nu-Swift, Ltd., Elland, Yorkshire. The new model has been specifically designed to combat fires in which inflammable liquids are involved, including alcohols, industrial solvents and electrical equipment, the flames being killed by fine powder directed on to them under pressure.

Tests have shown that a 4 lb powder charge in the hands of an inexperienced operator will quell a petrol fire 9 square feet in area, the comparative figures being 8 square feet for a 2-gallon air foam unit, 6 square feet for a 2-gallon chemical foam unit and for a 10 lb CO_2 unit, and 3 square feet for a 1 quart auto chlorobromomethane extinguisher. In experienced hands the extinguisher can deal with 14 square feet. The extinguishing capacity of the new unit is due to the nature and preparation of the dry powder, which is mainly sodium bicarbonate and the method of expulsion. The "oxidation" inhibitors (negative catalysts) present in the powder halt the chain reaction upon which the fire depends for its existence.

The dry powder, which is scientifically prepared so that all particles are regular in shape and size, is held with dried carbon dioxide in a sealed pressure charge so that it cannot be affected by atmospheric humidity. The ingredients are not liable to bacteriological spoilage and special treatment during manufacture eliminates any possibility of electrostatic coagulation. The extinguisher weighs 10½ lb and is 15¾in high and is fitted with a pistol grip, which enables accurate aim to be taken at the heart of the fire. When the knob in the operating head is struck a fan-shaped cloud of powder, 4ft wide by 2½ft deep, is expelled through a nozzle to a still air range of 10ft at 65 deg. Fah. The discharge time is eight seconds. The manufacturers state that the model, specially developed for Class B and C fires, will operate at a temperature of −40 deg. Cent. and has been approved by the Fire Offices' Committee. It is particularly suitable for fires involving hot oils, since no boil-over will be caused, and is also stated to be effective on surface Class A fires in textiles.

Industrial and Labour Notes

Shipbuilding and Engineering Wages

Last Tuesday afternoon it was announced that the strikes in the shipbuilding and engineering industries had been called off, and that there would be a return to work yesterday (Thursday) morning. This decision was reached at a meeting of representatives of the unions which form the Confederation of Shipbuilding and Engineering Unions. The meeting was summoned following a request by the Minister of Labour at the end of last week that there should be a resumption of work as courts of inquiry had been appointed to examine the disputes in both industries. The Minister has appointed two courts, the membership of both being the same, namely, Professor D. T. Jack, Brigadier L. C. Mandleberg, and Mr. C. J. Geddes.

The shipyard strike began on March 16, following the final rejection of a claim for a 10 per cent wage increase. At the beginning of last week, the Shipbuilding Employers' Federation met representatives of the Confederation of Shipbuilding and Engineering Unions again and there was general agreement about giving consideration to such matters as restrictive practices and productivity in resumed negotiations. On this basis, the employers made an offer approximating to a 5 per cent increase in wages, but that offer was rejected by the union representatives. At this stage the Minister of Labour decided to appoint the court of inquiry. In the engineering industries, the strike was organised by the unions to take place in "waves," and began on March 23. More workers—those in the London area—were called out last Saturday. Last Friday, the Engineering and Allied Employers' National Federation met the union confederation, and the discussions resulted in the offer of an increase, subject to certain conditions, of about 3 per cent. This offer was rejected and the Minister of Labour stated that he proposed to appoint a court of inquiry for the engineering wage dispute.

The court to examine the shipbuilding dispute began its sittings on Wednesday. It is expected that the reports of both courts will be presented to the Minister within the next two or three weeks.

Railway Wages

At the end of last week, the Associated Society of Locomotive Engineers and Firemen stated that it could not support the agreement over railwaymen's wages arrived at between the British Transport Commission and the National Union of Railwaymen. The British Transport Commission has undertaken to make a 5 per cent wage increase, on the understanding that there should be periodic reviews of wages and matters concerned with increasing the efficiency of railway working. These periodic reviews, it was urged, would be much more satisfactory than "recurrent and sometimes unco-ordinated wage claims." The N.U.R. and also the Transport Salaried Staffs Association have indicated their concurrence with the proposal.

The A.S.L.E.F., which agreed to a 3 per cent wage increase last December, has no objection to that increase being stepped up to 5 per cent, but it has intimated to the Commission that it could not subscribe to the conditions of the offer. In a statement, last Friday, regretting the A.S.L.E.F. decision, the British Transport Commission emphasised that its offer remained open. It was difficult to believe, the statement continued, that the A.S.L.E.F., from whose members the Commission was receiving such loyal service and co-operation, would persist in a refusal to give the reasonable undertakings contained in the offer.

Average Earnings

The Ministry of Labour has published details derived from its latest half-yearly examination of the weekly earnings of manual workers employed in manufacturing industries and certain non-manufacturing industries in the United Kingdom. The figures relate to the last pay week in October, 1956, and information, covering approximately 7,000,000 workers, was received from 67,500 establishments. The Ministry estimates that the returns received covered rather more than two-thirds of the total number of manual workers employed in the industries concerned.

In the industries included in the inquiry the average earnings in the last pay-week in October were as follows :—Men, £11 17s. 11d.; youths and boys, £5 2s. 4d.; women, £6 3s. 2d., and girls, £4 1s. 4d. In the manufacturing industries only, the earnings were : men, £12 5s. 7d.; youths and boys, £4 19s. 11d.; women, £6 3s. 8d., and girls, £4 1s. 9d. In this latter classification, in the group specified as "engineering, shipbuilding and electrical goods," the average weekly earnings were : men, £12 15s. 3d.; youths and boys, £4 18s. 4d.; women, £6 13s. 6d., and girls, £4 4s. 6d., the average hours worked in the week being 49, 44·7, 42·2 and 42·5 respectively. Taking the manufacturing and non-manufacturing industries together, the investigation showed that the percentage increases in average weekly earnings between April, 1947, and October, 1956, were : men 93 per cent ; youths and boys, 116 per cent ; women, 83 per cent, and girls, 102 per cent.

Since last October, when this inquiry into earnings was made, there have been increases in wage rates in a number of industries. The Ministry of Labour estimates that the effect of these increases has been to raise the general level of full-time weekly wage rates in the industries covered by its inquiry by about 1 per cent. At the end of February, the index of rates of wages (January, 1956=100) stood at 107 for all workers.

Industrial Production

An assessment of industrial production and of various factors associated therewith is made in the March issue of *Bulletin for Industry*, which is prepared by the information division of the Treasury. About last year, it says it was hoped that the disinflationary policies would encourage exports and check imports, that consumption would bear the main brunt, but that investment, while continuing to expand, would do so more slowly than in 1955. In the event in 1956, the *Bulletin* points out, exports rose at an accelerated pace (6 per cent in volume), while imports were checked, consumption flattened, and investment continued high, with less housing and with industrial development steadying at a higher level. The oil and petrol shortage, it is added, appears to have had no significant direct effect on output. According to the *Bulletin* these were the main factors determining the course of industrial production last year and so far this year. Total production has been steady, a small fall in manufacturing industry being roughly offset by greater activity in building and the public utilities. Demand from overseas has followed much the same pattern as at home, namely, a stronger demand for capital equipment than for consumer goods.

In manufacturing, the *Bulletin* continues, the group classified as "engineering, shipbuilding and electrical goods" covers a big range of industries, whose experiences varied a great deal last year. The output of the whole group was down 2 per cent—against the annual gain of 6 per cent between 1950 and 1955—but the total, it is stated, conceals two main currents. First, there was a further expansion of activity in the capital goods industries, and, secondly, there was a sharp cut in the consumer goods trades. Not all the capital industries expanded—for example, commercial vehicles and tractors—but the total showed a gain of something like 3 per cent. Outside manufacturing, the big rise last year was 6 per cent in building. The value of new work by building and civil engineering contractors, the *Bulletin* says, rose by £200 million last year, about one-third of this increase being industrial building and another third public authority building other than housing. Fewer houses were built for local authorities than in 1955 and 12 per cent more (in value) for private owners, though starts on both kinds of housing tapered off during last year. Completions of new industrial premises totalled 34,000,000 square feet in the first nine months of 1956, or over 20 per cent more than a year earlier, but the rate of expansion diminished as the year went on. In the last quarter the area of industrial building approved was 11 per cent less than a year earlier. In mining and quarrying, the *Bulletin* goes on, output was virtually unchanged in 1956, but this year, so far, there has been a significant increase in coal output.

Summing up, the *Bulletin* emphasises that the most significant development last year was the increased share of capital goods and building, which were able to use some of the resources freed elsewhere. By the end of the year many of the industries where output had fallen appeared to be stabilised and building activity showed signs of steadying. But, the *Bulletin* urges, investment demand is still the main expansionary force at home, and, after the private investment boom of the last two years, public sector investment may well now make the running. Overseas, the continued expansion of world demand provides real opportunities for a further growth of exports, the pace of which will largely determine the course of industrial output.

N.E. Coast Steelworks Development

The Iron and Steel Board has given its approval to an improvement scheme at the West Hartlepool works of the South Durham Steel and Iron Company, Ltd. The programme includes the installation of seventy-eight coke ovens on a new site, as distinct from the additional twenty-six ovens on the existing site, together with the necessary by-product plant and a coal-handling and blending plant. The ore-handling and stocking plant at the West Hartlepool works is to be extended, and a 27ft 6in diameter blast-furnace is to be built, there being provision for the construction of a second furnace, of similar dimension, at a later date. A new melting shop will be built containing six 350-ton open-hearth tilting furnaces and two mixers, each of 600 tons capacity. There is also to be an ingot preheater furnace and eight soaking pits, a new slabbing mill with a rolling capacity of 1,500,000 ingot tons a year, and a four-high 12ft 6in plate mill.

The total estimated cost of these developments is £43,000,000, which will be spread over five years. The site selected for the new plant is at Greatham, the ground acquired by the company having been formerly an airfield. It is anticipated that the new plant, when completed, will provide work for more than 2500 people.

Britain's Machinery Exports

A report on United Kingdom export trends in recent years, which has been prepared by an interdepartmental working party, is analysed in the current issue of the *Board of Trade Journal*. Among other matters, this report points out that although the United Kingdom's share of world exports of machinery and vehicles fell between the first three-quarters of 1955 and 1956, her share of the trade in electrical machinery was maintained, and only a little ground was lost in other machinery exports. The main reason for the fall in the United Kingdom's share of trade in the whole group was failure to keep up with the expansion of world exports of motor vehicles.

The Board of Trade says, however, that there would have been a rather greater decline in the United Kingdom's share of machinery exports but for the bunching of deliveries of ships and boats, and aircraft and engines, exports of both of which were nearly 75 per cent higher in the first nine months of 1956 than in the corresponding period of 1955. At the same time, Japan almost doubled her exports of machinery and vehicles (mainly owing to a very sharp rise in the export of ships), whilst Germany also increased her exports more than the average for the world. The share of the U.S.A., however, continued to fall.

Geesthacht Pumped Storage Scheme

In October, the first of three 35MW sets of the Geesthacht pumped storage power station is to go into service ; two further sets are to follow in 1958, thus completing the first stage of the scheme, which includes a storage reservoir of 3,000,000 cubic metres. Situated on the River Elbe, 35km upstream from the centre of Hamburg, the station will contribute substantially to the economy of Hamburgische Elektrizitätswerke A.G. During a recent visit we were able to see the progress achieved since work was begun on December 6, 1955. Eventually there will be six sets, totalling 210MW. The scheme is being carried out in conjunction with a barrage which is scheduled for completion in three years' time.

FOR many years dredging operations have been carried out in the port of Hamburg and the River Elbe between Hamburg and the sea. This has led to a progressive erosion of the upstream river bed and a lowering of the water level at low tide and during periods of minimum flow, as in the summer. In order to improve matters it was decided some years ago by the Hamburg River and Navigation Authority to build a barrage and weir across the Elbe just below Geesthacht (see Fig. 1) at River km. 586, in order to raise the water level by 3·5m. A side canal, approximately 3km long and provided with a double lock, is to be built for the use of shipping. Measuring 230m by 25m, the lock will accommodate trains of up to ten fully laden 1000-ton barges ; it is to be equipped with vertical lift gates. Preliminary work on the barrage scheme was commenced in December, 1955.

While the Elbe barrage was prompted by considerations of river regulation and navigation, the proposed creation of a reservoir of water, at the foot of the Geestrücken hills and only some 35km from the centre of Hamburg, led Hamburgische Elektrizitätswerke to consider the building of a pumped storage power station.* The company has at present an installed capacity of 620MW, soon to be increased to 700MW, all of which is in the form of thermal plant. A pumped storage station was therefore considered to be very desirable for supplying morning and evening peak loads, and as a standby which could be put into use at any time in less than two minutes. Investigation showed that a reservoir of 500,000kWh could be constructed, the output from which could be increased to 580,000kWh per day if pumping were carried out at midday as well as during the night. For the next few years an installed capacity of 105MW, in the form of three 35MW sets, is thought to be sufficient. This can later be increased to 210MW by installing three more sets.

At Geesthacht the head available between the pumped reservoir and the river is of the order of 70m to 85m. In view of this low figure it was necessary to keep the layout and construction as simple as possible, as it was considered that the combined cost per kilowatt-hour of thermal and hydro-electric generation should not exceed the purely thermal generating cost. The capital cost of construction has been estimated to be about DM.600 per kilowatt for the first stage and DM.525 per kilowatt for the final stage (1953-54 prices). These figures are well below the curve of specific cost per kilowatt against available head, plotted from the data of four other pumping stations, the heads of which range from about 140m to 310m† ; extrapolation of this curve to 85m head gives about DM.700 per kW.

Work on the storage scheme began on December 6, 1955, and at the time of writing is in advance of schedule. It is anticipated that the first 35MW set will be commissioned in October of this year, two further sets following in 1958. The principal data are assembled in Table I.

TABLE I—*Geesthacht Pumped Storage Scheme (Stage I)*

Reservoir :	
Storage capacity	3·3 million cubic metres
Earth movement	2·25 million cubic metres
Max. water level above datum	90·6m
Minimum water level above datum	76·6m
Dam crest level above datum	92·6m
Dam volume	1·5 million cubic metres
Intake and penstocks :	
Number of gates	Six
Number of penstocks	Three
Penstock diameter...	3·8m
Total length, each...	717m
Power station :	
Horizontal Francis turbines ..	3×35MW, 32–43·5MW 51–60 cubic metres per second, (each mean ; 35MW, 57 cubic metres per second)
Turbine speed	214 r.p.m.
Runaway speed	455 r.p.m.
Generators	3×43·75MVA, 10·5kV (max. 50MVA)
Generators as motors, each ...	34·5MW
Pumps	2×31MW, 33 cubic metres per second, single-stage
Station transformers	2×10kV/10kV/110kV, 90MVA

Reservoir.—The site finally selected was one of the heights of the Gülzower Forst, east of Geesthacht, between Federal Highway No. 5 and the Elbe near km. 582. Before construction began the site had a maximum elevation of 88m above sea level. Underneath the top soil the ground consists mostly of sand, gravel and moraine marl. Compressive strength of the marl was found to be 500 kg to 1500 kg per square centimetre, i.e. it was practically non-compressible. Deeper layers of peat were found to have been compressed to the consistency of lignite and were therefore also considered to be sufficiently load bearing. Only some near-surface peat and bog had to be removed.

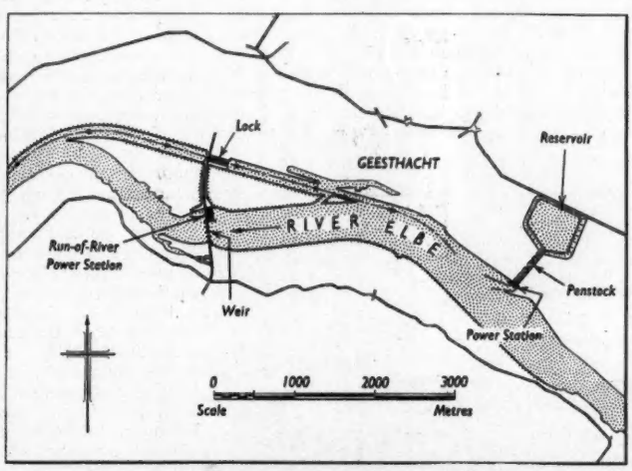


Fig. 1—Geesthacht pumped storage scheme and river barrage

The dam is in the shape of a pentagon of unequal sides, with a total length of about 2000m. The dam has inner and outer slopes of 1 : 2·5 and 1 : 3·5 respectively and stands 12m to 24m above ground level. The crest, which is 6m wide, carries a road giving access to the intake structure. Approximately 1,500,000 cubic metres of sand and gravel were used in constructing the dam, the material being obtained from the reservoir.

Since no impermeable layer is present in the subsoil within a reasonable depth, it was not possible to build the dam with a waterproof core based on such layer. The method of waterproofing chosen was to apply a 5cm thick layer of bitumen-sand to the bottom of the reservoir and the water face of the dam. This is being covered by a double layer of asphalt, 6cm thick at the reservoir bottom and 7cm thick at the sides, and a top seal of 5 kg per square metre of mastic.

At the outside foot of the dam a horizontal gravel filter is provided, with access to a drainage ditch, in order to give warning of any seepage water and drain it away. Similar gravel layers are placed under the sealing surface and at the dam base, at points where clayey soil was encountered, in order to prevent frost damage and to give drainage. As a protection against erosion the outside face of the dam is being covered by a 15cm layer of humus and will probably be planted with shallow-rooted shrubs.

Between March and September, 1956, over 2,000,000 cubic metres of earth were moved, out of a total required of nearly 2,250,000 cubic metres. Subsequently more than 165,000 square metres of the 5cm sand-bitumen layer have been placed. Sixty-one excavators, graders and transporters were employed, requiring a staff of 230 men, of whom 190 worked in two daily shifts as drivers or mechanics. Fuel consumption amounted to 0·6 litre per cubic metre of earth moved.

Intake Structure.—The intake is a reinforced concrete structure approximately 27·5m by 58m by 29m high, requiring some 22,000 cubic metres of concrete (Fig. 2). It is flanked on the water side by two retaining walls, which are joined to the bituminous lining by five layers of corrugated copper sheet, in order to prevent the formation of cracks. At the inner and outer end of the foundation sheet piling has been carried out to a depth of 6m, in order to prevent danger to the structure should water seepage occur. There are six intakes, as required for Stage II, and these are carried out on the air side in the form of two flat reinforced concrete blocks, each housing three 3·80m diameter conduits. The length of this portion is 105m.

On the water face of the structure are the intake screens, which are in three parts and can be raised ; they can be replaced by stoplogs for closing each intake. The flow is controlled by oil-operated rising gate valves, 5·2m by 5m high, followed by separately housed, gravity-operated butterfly valves for emergency shut-off. A 30-ton portal crane is provided for maintenance.

Penstocks.—The 105m long reinforced section of the penstocks will be covered over with earth-fill. The penstocks are continued in the form of steel conduit, three 3·80m diameter pipes being laid for Stage I. Placed on supports spaced at distances of 24m, the steel pipes extend for a distance of 375m at a slope of 8·4 per cent, the same as that of the reinforced concrete conduit. This section is followed by a length of 132m, having a gradient of 31·3 per cent and anchorages for the pipes at both ends. Each pipe is fitted with two expansion joints and, near the power house, with a flexible joint to allow for settlement. At the lower anchorage each pipe branches off to the pump and turbine. A permanent materials hoist has been installed between the two groups of pipes.

Turbine House.—The raising of the water level to 3·5m above datum, and the requirement of a pump intake head of 2m, make it necessary to have the centre line of the sets 1·5m above datum, thus fixing the floor level at 0·3m above datum. A level of 8·5m above datum being regarded as free from flood water, the machine house takes the form of a trough of 9m internal height (Fig. 3). Since portal cranes with about 9m lift above ground level have to be installed, a hall for Stage I enclosing the cranes would have measured 100m by 16m by 13m high and would have constituted a very expensive item. It was therefore decided to omit the hall and to close the machine room with removable hatch covers. Concrete beams supporting these covers at a height of 1m above ground level are

*R. Meister, "Grösse und Wirtschaftlichkeit von Pumpspeicherwerken," *Elektrizitätswirtschaft*, Vol. 55 (1956), No. 10, pages 316–320.

† B. Jansen and K. H. Haager, *Elektrizitätswirtschaft*, 53 (1954), pages 646 and 704.

fitted with windows and ventilators. Two 125-ton portal cranes span the 15m wide machine pit, which additionally is to have two internal 5-ton overhead cranes so that minor repairs can be carried out without removing the hatch covers.

Ancillary plant, such as coolant pumps, air compressors, turbine governors and control equipment, and emergency diesel generating sets, are housed in a section of the trough adjoining the machine room on the side towards the river. The upper part of this section houses the control room. This will be at the westerly end of the Stage I machine room but in the centre of the completed machine room, which will be 170m long.

The power house structure is situated at right angles to the penstocks and is divided into blocks of 30m length, each for two sets, with expansion joints between blocks, which are to be made watertight by means of copper sheet. A rail track to one end of the station permits material to be unloaded by the power house portal cranes. About 50,000 cubic metres of reinforced concrete are being placed. The "Ibag" concrete mixing station is almost completely automatic and has a daily capacity of 1200 cubic metres. One to three men are required to operate it.

Towards the reservoir side of the machine trough, and above the pipe anchorages, are the servos for the valves, and the 10kV switchgear and busbars. The turbine valves are within the main machine floor space and therefore accessible to the cranes, but the slide valves are situated in lateral extensions of the trough outside the crane span. In order to avoid the necessity for increasing the portal span to 20m and in addition fitting the cranes with 7m jibs of 100 tons capacity, provision was made to enable the valves to be transported into the machine house on rails. With this arrangement it was possible to site the outdoor station transformers on top of the side extensions of the trough and so avoid the need for separate foundations.

Tailrace.—The power house is about 200m from the river, with which it will be connected by a curved tailrace 300m long, laid out for the Stage II flow of 342 cubic metres per second. The race is designed to give a cross-stream velocity not exceeding 0·1m per second in order not to interfere with navigation. Near the station, where flow speeds of up to 6m per second are reached, a 20m wide concrete apron will be placed to prevent erosion. This is followed by a stone apron of decreasing thickness and rising 1·5 per cent towards the river. Guide walls on the concave bank and in the centre of the race are to be built for Stage I and Stage II respectively.

Machinery.—Three horizontal Francis turbines of maximum 59,000 h.p. (43·5MW) will be installed for Stage I. Each turbine will be directly coupled to a 35MW, 43·75MVA generator. Normal speed is 214 r.p.m. and runaway speed 455 r.p.m. The flow varies between 51 cubic metres and 60 cubic metres per second (mean flow 57 cubic metres per second). The turbine runners have a diameter of 3·15m.

In the first instance only two pumps will be installed. These will have a mean discharge of 33 cubic metres per second each, and so are capable of filling the reservoir in just under fifteen hours. For the final stage it is intended to have four pumps; whether more than four are required will be shown by experience.

The pumps are single stage and fitted with manganese steel impellers. They are coupled to the generator motors during standstill by means of gear couplings, and are brought up to synchronous speed by the turbines, which are then aerated. Running-up will be largely automatic and, it is stated, will take less than 100 seconds.

Generation is at 10·5kV, and the generators are designed for a thirty-minute overload of 50MVA each, or a total of 120MW. Since space at and near the station is very limited, an unusual electrical arrangement is being adopted. There are to be three station transformers, of which two are to be installed for Stage I. These will have double primary windings to which the sets will normally be connected in pairs. Should a failure occur in one transformer, the busbar arrangement permits all three sets to be connected to the other. The transformers have a nominal capacity of 90MVA and each is capable of carrying the full load for up to thirty minutes without exceeding thereby the short circuit capacity of the 10kV side, which amounts to 1000MVA. There are to be no high-voltage circuit breakers at Geesthacht, and power will be transmitted at 110kV to Tiefstack, 25km away.

The pumped storage scheme is being built by a number of firms under the overall direction of Siemens-Schuckert Bau-Union A.G., Berlin and Erlangen. Turbines are supplied by J. M. Voith G.m.b.H., Heidenheim (Brenz), while the pumps are by Escher Wyss G.m.b.H., Ravensburg. The generators and main transformers are being built by Siemens-Schuckertwerke, Berlin.

Fig. 3—Excavation for power station, seen from the west. The total quantity is about 135,000 cubic metres, including sixty wells, 20m to 38m deep, for dewatering. In the background is the concrete mixing plant

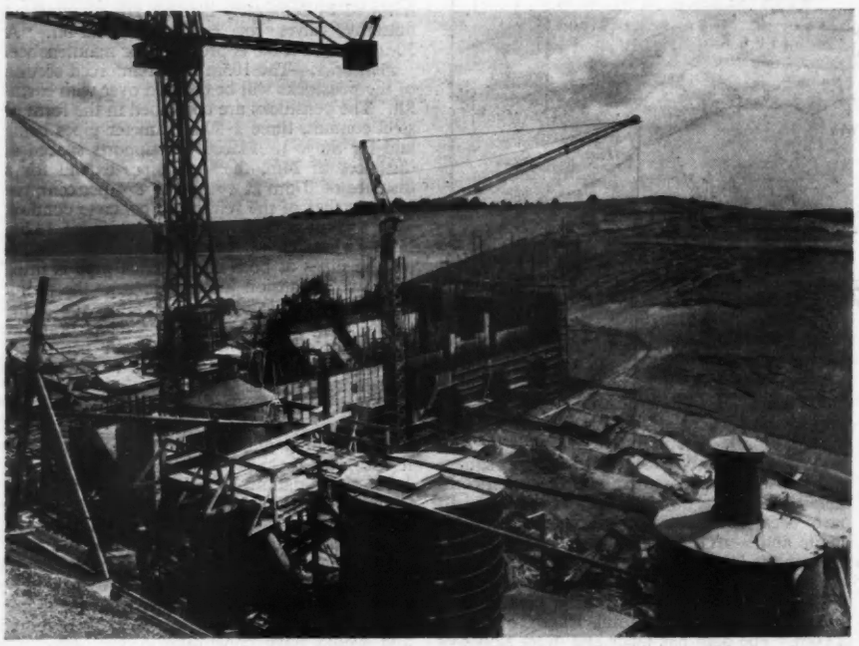


Fig. 2—Reservoir and intake structure (six intakes). Two reinforced concrete penstocks, 105m long, and containing three conduits each, were subsequently built; they will be covered over. The remainder of the penstocks will be steel pipes, those for stage 1 being on the right. In the foreground is the sand and gravel preparation plant

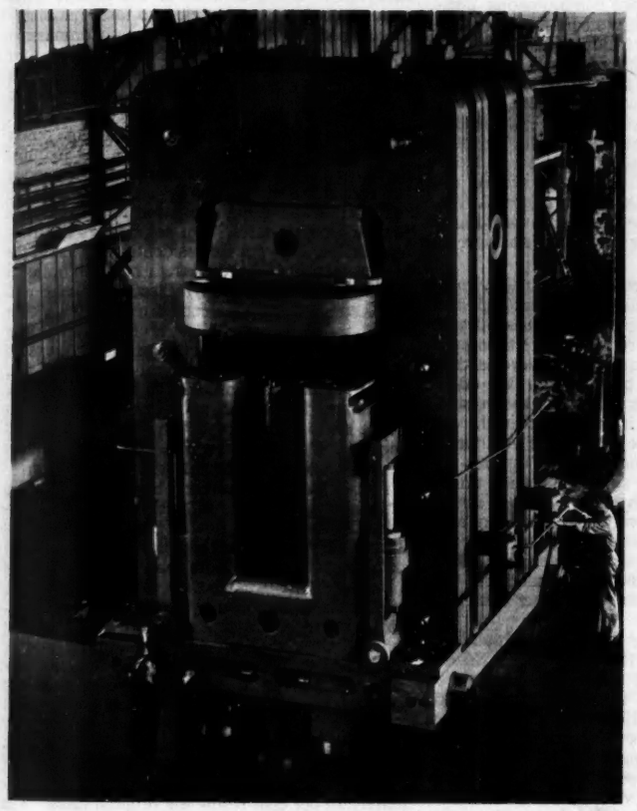
Liquid Petroleum Gas Plant in Austria

A liquid petroleum gas filling plant was recently opened at Niklasdorf, near Leoben, Austria, by the British Petroleum Company's Austrian associate, BP Benzin und Petroleum A.G.

Stated to be the most up to date in Central Europe, this plant can fill up to 500 bottles a day of butane and propane. The gas, which is used for cooking, heating, refrigeration and lighting in areas where no town gas is available, is brought to the plant by rail or road tank wagon. A conveyor belt brings empty bottles to three automatic filling machines where they are filled. By resting the bottles on weighing machines, the flow of gas is automatically stopped when the correct weight has been reached. Before despatch to consumers, the bottles are tested for leaks.

Large Press for Aircraft Construction

The increased stresses to which modern supersonic aircraft are subjected have brought it about that the traditional construction of airframes using light alloy sheet in single or multiple thickness is no longer adequate for many components. At first it became the practice to machine workpieces of aluminium, magnesium and titanium alloy from the solid. Since machining is a comparatively lengthy procedure and also destroys the fibrous structure of the metal, the tendency has been to replace machining by pressing and forging. Our illustration shows a 15,000-ton hydraulic press built by G. Siempelkamp and Co. Maschinenfabrik, Krefeld, German Federal Republic, for an aircraft factory at Toronto, Canada. Including planning, design and construction, the press is stated to have been completed eleven months after receipt of the order. By contrast with the traditional construction which comprises cast steel cylinders, platens, &c., held together by forged columns screwed at the ends, the press consists of a number of frames made of Siemens-Martin steel which are assembled in a number of packs. Each frame is machined from the solid without any bolted or welded connection in the direction of tension. This design which has been developed by Siempelkamp over the last thirty years, avoids the potential sources of trouble to which the column design is subject—cavities in the steel



15,000-ton press for aircraft components

castings, slag inclusions in the forged columns, hair cracks and stress concentrations.

Special arrangements, it is stated, have been made to permit the pressing of unsymmetric workpieces and the taking-up of the resulting eccentric loadings, while maintaining the parallelism of the working surfaces independently of the amount of load eccentricity along the length of the platen.

Workpieces up to 1·50m by 3m or a corresponding number of smaller pieces can be pressed at the rate of 60 cycles per hour. This high rate of operation is largely achieved by loading and unloading mechanisms which are to a great extent automatic. Both the press and the materials handling devices are operated by means of water. Pressures of up to 330 kg per square centimetre are used. The pumps are powered by electric motors totalling 600 h.p., and the press has a weight of 560 tons. It was transported to Bremen in five sections, using a special low loading railway wagon.

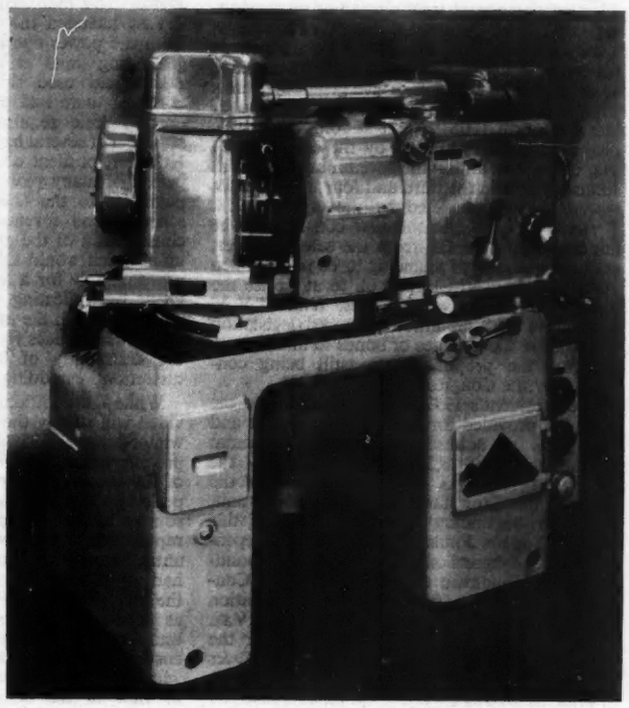
Large Oil Tanker "George F. Getty"

The first of four oil tankers of 51,850 tons deadweight ordered from French shipyards by the Tide Water Associated Oil Company of the United States has recently been delivered upon completion of trials. The plans were prepared by the Chantiers de l'Atlantique (Penhöet-Loire), where two of the ships were ordered, the other two ships being allocated to the Ateliers et Chantiers de France. The "George F. Getty," was launched from the Saint Nazaire yard in July of last year, and the following are the ship's main dimensions: length overall, 785ft 7¾in; length between perpendiculars, 747ft 11in; breadth moulded, 102ft ½in; depth moulded, 51ft 8in, and maximum draught loaded, 38ft 6in. When fully loaded the tanker has a displacement of 67,100 tons and air conditioning is provided in the major part of the accommodation for the crew, numbering sixty-four. There are four 5-ton, two 3-ton and two 2-ton derricks and the deck machinery consists of three winches, a capstan and a windlass, all of which are steam-driven and steering is effected by an electrical hydraulic gear.

There are two longitudinal bulkheads and eleven transverse bulkheads, forming thirty-six cargo oil compartments having a total capacity of 461,500 U.S. barrels; for loading and unloading the oil there are four 1130 tons per hour turbine-driven pumps. Electric power for the various ship services and the auxiliary machinery is developed by two 650kW, 450V, turbine-driven generators and there is also one 75kW, 450V, generator driven by a six-cylinder, four-stroke Renault diesel engine of 115 h.p. The ship is propelled by a single set of C.E.M.-Parsons double-reduction geared turbines, which develop 19,000 s.h.p., to give the ship a service speed of 16·5 knots, and which maintained 17 knots on trial. The necessary steam is supplied at 600 lb per square inch and 850 deg. Fah. by two Foster Wheeler marine boilers. A second ship, the "Minnehoma," was launched in January by the Ateliers et Chantiers de France.

Hobbing Machine for Small Cyclo-Palloid Bevel Gears

We have received details of the Klingelnberg "Model FK41" hobbing machine for small-size cyclo-palloid bevel gears, which may be seen in the accompanying illustration. The principle of producing the gear by means of circular cutters is the same as that of the earlier "Model FK40," but the cutter head and its drive have been completely redesigned. The gearing is produced in the same manner as on the large Klingelnberg machines, but as the amount of metal removed is quite small, the cutter design can be simplified without detriment to the performance. In the redesigned machine, cutter heads are available with double the number of cutters, thus giving increased output. Setting for the amount of flank contact desired, is both easy and reliably repeated, and the flank contact can be set independently for the forward and reverse motion of the gears. Tooth thickness and gash spacing can be equal or unequal, as required. It is possible to select a spiral angle common with bevel gears, or to set the machine for zero spiral angle. Either normal or hypoid bevel gears may be produced. Like the large cyclo-palloid gears, the bevels have teeth of equal depths at the small and large diameter, an important factor in obtaining a high transmission efficiency. The machine incorporates an infinitely variable drive with speed indicator. Made by W. Ferd. Klingelnberg Söhne, Remscheid, German Federal Republic, it is marketed in Great Britain by Sykes Machine Tool Company, Ltd., Staines, Middlesex.



Hobbing machine for small cyclo-palloid bevel gears

Wages and Salaries in Switzerland

In the period April-October, 1956, wage rates in Switzerland underwent an average increase of 1·5 per cent, exceeding the level of October, 1955, by 3·7 per cent, and that of October, 1939, by 88·9 per cent. Since October, 1939, skilled workers have had their rates increased by 86·9 per cent, while unskilled workers' pay is 98·4 per cent above 1939.

Progress of the Tennessee Valley Authority

BY OUR AMERICAN EDITOR

No. III—(*Concluded from page 507, March 29*)

Future Power Supply

THE Authority was concerned during the past year with problems of power supply to meet the growing needs of the region. Unless construction of new generating capacity were undertaken promptly, inadequate capacity and possibly power shortages were foreseen in 1957 and 1958; even if construction were started promptly the margins of capacity over forecast demands would be slim. To bring the power supply at the end of 1957 as near as practicable to the estimated demands and to provide at least a minimum of supply over demand before the end of 1958, in the autumn of 1955 the T.V.A. proposed the addition of possibly as many as seven new generating units depending on developing conditions. However, the T.V.A. recommended to the U.S. Bureau of the Budget, as the course of action that appeared most desirable at the time, the addition of five generating units with a total of 900MW of capacity. One of these, a fourth 180MW unit at John Sevier was proposed to be completed by the end of 1957. The other four units—the seventh and eighth at Johnsonville and the third and fourth at Gallatin—were to be completed by the end of 1958. T.V.A. proposed that the new construction be initiated with revenues from the sale of power, with the question of financing to be re-examined upon the passage of legislation to authorise the T.V.A. to issue revenue bonds. While T.V.A. and others had submitted proposed legislation to authorise the issuance of bonds to finance new capacity, the proposals were still being considered by the Congress.

The President's 1957 budget submitted to the Congress provided for the John Sevier unit and two units at Johnsonville. A supplemental appropriation of 3,500,000 dollars for the fiscal year 1956 was requested to provide the funds required for starting the John Sevier unit, funds for continuing the construction of this unit and for the Johnsonville units to be dependent upon congressional approval of the bond-financing amendment to the T.V.A. Act. Congress rejected the 3,500,000 dollar appropriation request and indicated its intention that T.V.A. should employ power revenues to pay for the addition of new units at existing steam power stations. The background of this decision was, in brief, as follows:

In legislation enacted in 1939 enabling the purchase by T.V.A. of facilities owned by the private power systems in the Valley region, the Federal Government accepted responsibility for supplying the power needs of the region. Relying upon this commitment, scores of cities, rural co-operatives and large industries, many of the latter strategically important to national defence, have invested hundreds of millions of dollars in distribution facilities and manufacturing plant in the expectation that a prudent management would supply increasing amounts of power as the economy of the Valley region demanded it. During the past fiscal year the lack of funds from appropriation sources raised serious doubts as to whether this commitment could be fulfilled. The annual budgets of the President for three successive years had contained only the single 3,500,000 dollar recommendation for additional appropriations to finance the installation of new generating capacity, and Congress had not provided such appropriations. Recommendations by the T.V.A. Board and the Bureau of the Budget for legislation authorising T.V.A. to finance new capacity with bond issues backed by T.V.A. power revenues were before the Congress, but it appeared that early enactment was unlikely. Yet the economy of the Valley region was stepping up its demand for electricity at the rate of nearly 15 per cent a year. Since new generating capacity takes about three years to build under normal schedules, this rate of growth would mean a serious power shortage during the 1957–58 winter season unless the construction of such capacity was begun at once. The need for a means of financing was urgent if such a shortage were to be avoided.

Since its inception, Congress has recognised that T.V.A. as the manager of a large Government investment in electric power facilities must have much of the flexibility and initiative of a private enterprise. This concept has been in conformity with the principles of American business in which the shareholders as owners of a larger operation entrust the intricacies of its management to trained, hired experts and managers. The management authority granted to T.V.A. included the right to use the revenues from the power operation to finance additional generating units at existing projects, and the Board had used this authority in the past, although there had been no occasion to do so on the scale required for simultaneous construction of several large new steam-electric units. However, prudent conservation of funds over a period of many years had brought the agency's payments to the U.S. Treasury well ahead of schedule and revenues were available for the construction of the proposed new steam-electric units which would safeguard the Valley region's power supply for a few additional years. Congress, by indicating this course of action, reaffirmed both the legal authority of the T.V.A. to use its revenues for the purpose involved and the desirability of its exercise of managerial discretion in so doing.

While the additional generating capacity provided will supply the Valley region through the winter peaks of 1959–60, power revenues will not provide sufficient capital to meet more than part of the region's power requirements beyond that period. T.V.A. must have access to other sources of funds if power to nourish the present rapid economic growth is to be provided. In anticipation of its future needs, the Authority had requested tenders and obtained options on the major equipment for seven generating units, as mentioned above, in order that it could establish a place in line with manufacturers and ensure delivery of the equipment on schedule when needed. This was a farsighted procedure in view of the demands being made on the manufacturers of generating and other electrical equipment.

Immediately after the congressional action, T.V.A. began work on the fourth John Sevier unit, which is expected to bring the assured load-carrying ability of the T.V.A. system to 9683MW at the end of 1957. At that time, the demand on the system is presently estimated at 9650MW, so that the margin of capacity over load will be less than 1 per cent. Near the end of the fiscal year, the T.V.A. initiated construction of the seventh and eighth Johnsonville units and the third Gallatin unit, to be financed with power revenues. They are planned, on a tight schedule, to be in operation in the winter 1958–59, bringing the assured load-carrying ability of the system to 10,253MW. At this time, the load is expected to be at least 10,000,000kW, indicating a margin of capacity over load of only 2½ per cent.

The narrow margins indicated for the end of both 1957 and 1958 are too small to ensure that there will not be power shortages. Such shortages could result either from delays in meeting the tight construction schedules or from the development of loads in excess of those now projected. For example, the loads could be greater if the A.E.C. desired to continue its operations at current levels or if T.V.A. should be called on to supply power to Memphis after the summer of 1958 in the event that the city cannot complete its generating capacity in time to meet its requirements. A review at the end of the year of probable power revenues indicated that the fourth Gallatin unit and the ninth and tenth Johnsonville units can also be paid for completely from power revenues. Accordingly, to take advantage of favourable equipment options and allow as much time as possible for completion of the units to meet power demands in 1959, T.V.A. decided shortly after the end of the 1956 fiscal year to proceed with construction. When this programme for generating capacity expansion is completed, the installed capacity of the T.V.A. system will be 11,245,485kW and the assured load-carrying ability will be about 10,793MW.

Local Distribution

T.V.A. power, sold at wholesale, reaches the consumers through the distribution operations of 149 municipal and rural co-operative associations and two small private companies. These retail distributors had, on the whole, good financial results during the fiscal year 1956. Many of them were able to give their customers the benefits of substantial rate reductions. Thus the T.V.A. power programme continues to demonstrate the effectiveness of a policy of encouraging the widespread use of electricity through low rates. The mass-production mass-marketing concept of the electricity business, depending on large-scale sales with a small profit on each unit sold, continues to be successful. Rate reductions by the distributors are in contrast to the general trend of a gradual increase in electric rates nationally as reported by the Federal Power Commission during recent years. A milestone was reached during the 1956 fiscal year when the average residential use of electricity in the T.V.A. area was double the national average for the first time. The use in the homes supplied with T.V.A. power averaged 5812kWh compared with the national average of 2879kWh. Average cost of electricity for residential use in the T.V.A. area was 1·16 cents a kilowatt-hour, compared with 2·62 cents for the United States. For some years the average cost per kilowatt for residential service in the T.V.A. area has been less than half the national average. The Chattanooga Electric Power Board reported an average residential use of 10,007kWh for the fiscal year 1956. It is believed that Chattanooga is the first large city to exceed 10,000kWh in average annual residential use. When T.V.A. was established in 1933, the average annual residential use, both in the country as a whole and the present T.V.A. service area, was about 600kWh; the average cost to residential consumers was 5½ to 6 cents a kilowatt-hour.

In the face of a continuing trend toward higher rates elsewhere in the United States, thirty distributors of T.V.A. power reduced their rates during the year. These reductions are estimated to save their customers more than 1,000,000 dollars annually. This was the largest number of rate reductions to be made by distributors of T.V.A. power in any year except 1946, the year following the end of World War II. A number of rate reductions were in order during the war, but they were delayed in order not to encourage an increased use of power. Because the original T.V.A. rates were higher than needed by many of the distributors, two schedules of lower rates have been established. One is about 10 per cent below the original rates and the other is approximately 20 per cent below the original rates. The reductions during 1956 brought to fifty-two the number of systems which now apply rates below the original rates. At the close of the fiscal year a number of additional distributors were in a financial position to justify rate reductions, and such reductions were expected to be made soon. The earnings of several of the distributors now applying the lowest level of rates are, even now, greater than necessary. At the request of these distributors, T.V.A. is developing a still lower schedule of rates.

Fertiliser Development

The decade since the end of World War II has seen revolutionary changes in the use and production of fertilisers. The use of commercial fertilisers, once largely a southern practice, to-day is becoming nation-wide. Farmers in the South Atlantic States no longer lead the United States

in fertiliser consumption. Since 1953 the East North Central States—Ohio, Indiana, Illinois, Michigan, and Wisconsin—have become the foremost users. In the Middle West and the Far West fertiliser use is growing rapidly. More fertiliser is now being used in regions far from the sources of raw materials. Natural deposits of phosphates, for example, are limited in number and location. The largest reserves are in four Western States ; lesser reserves, but more highly developed ones, are in Florida ; the smallest significant deposits are in Tennessee. All are remote from large farming areas where the soils need phosphate to retain their fertility and productive capacity.

The growing fertiliser use in these regions has required more emphasis on high-analysis materials. Fertilisers containing a high percentage of plant nutrient can be transported, bagged and spread on the land at a lower cost to the farmer per unit of plant food. Farmers to-day are getting on the average 50 per cent more plant nutrients per ton of fertiliser than they did in 1935, with consequent savings in their fertiliser costs. The trend toward higher concentrations continues, supported by developmental research conducted by the T.V.A. The T.V.A. fertiliser programme serves three major functions leading to the improvement in the operations of the fertiliser industry and the benefit of farmers : (1) the Fertiliser-Munitions Development Centre at Muscle Shoals, Alabama, provides research in chemistry and chemical engineering aimed at constant improvement in the quality of fertilisers and constant progress in lowering the costs of fertilisers to farmers. The Centre is the only facility in the United States equipped to carry fertiliser research from the laboratory through pilot-plant stages to plant scale operation. (2) Through co-operative arrangements with the agricultural experiment stations of fourteen States, new and improved fertiliser materials are tested for use on widely diverse kinds of soil in all major sections of the country ; the results of these tests help guide further research at Muscle Shoals. (3) The processes by which the individual farmers learn to use modern commercial fertilisers and learn their place in the individual farm economy are speeded by educational programmes in which T.V.A. fertilisers are used in actual farming operations as demonstrations. In these programmes the land grant colleges, other agricultural agencies and private and co-operative distributors play an active part in the educational process.

In the field of small-scale research, work went forward during the year on a number of projects designed to improve products or the methods of manufacture. Several hundred gallons of superphosphoric acid were made experimentally. The product is 40 per cent more concentrated than ordinary electric furnace acid yet remains fluid at ordinary temperatures. New interest was aroused in this product of elemental phosphorus because it offers shipping economies over commercial acid and has possibilities as a raw material for high-analysis liquid fertilisers. The pilot plant ammoniator developed by T.V.A. was used in continued tests on the problem of hydrolising and ammoniating calcium metaphosphate in the production of high-analysis fertilisers. Granular fertilisers with excellent physical properties were made by treating calcium metaphosphate with sulphuric or phosphoric acid and then ammoniating with nitrogen solution or ammonia. This treatment increased the water-soluble phosphate in the material from virtually none to a range of 15 to 30 per cent. The process can be carried out in the T.V.A. ammoniator which has been installed by many commercial factories.

In other pilot plant operations, high-analysis granular fertilisers were made by various procedures as part of a co-operative T.V.A.-U.S. Department of Agriculture project, and improved processes were developed for several grades of mixed fertilisers. Methods were developed for incorporating materials not hitherto used, such as coarse muriate of potash and urea solutions. The work was considerably influenced by contacts with some sixty commercial producers operating T.V.A. ammoniators, and results were conveyed to them by reports, calls and visits. A new project was started for improving conventional fertiliser processes. The first objective was to speed production of normal or " ordinary " superphosphate by developing a continuous process which would eliminate the weeks or months of storage normally required for curing. In small-scale work using finer phosphate rock and higher ratios of acid to rock, it was found that ordinary superphosphate could be produced with 96 per cent of the phosphate in a form available to plants only an hour after mixing. The product was ready for immediate ammoniation and mixing with other ingredients. The project was being carried further in pilot plant work. In a similar undertaking, it was found that products containing 14 or 20 per cent each of phosphate and potash could be made in the continuous ammoniator from phosphate rock, superphosphate, sulphuric acid, and potash, with only one to three days of curing required.

Fig. 11—Continuous ammoniator developed by the T.V.A. research laboratory at Muscle Shoals, Alabama

In a revival of studies carried on ten years ago, work was done on the use of hydrochloric acid, potentially available at low cost from numerous chemical processes in producing fertilisers. A di-calcium phosphate product of 35 per cent plant nutrient concentration was produced on a small scale and further tests were to be made. Additional work also was done during the year on regenerating sulphuric acid from phosphogypsum, a by-product of the wet process for producing phosphoric acid. A process which appears economically favourable under certain conditions was developed, but some technical problems remained to be solved.

Research on liquid fertilisers continued. In laboratory studies it was found that unusually concentrated liquid fertilisers, containing as much as 11 per cent nitrogen and 37 per cent phosphate, could be made by ammoniating superphosphoric acid. The solutions were stable at freezing temperatures. It was found also that wet phosphoric acid, which is cheaper than commonly used furnace acid but less pure, could be ammoniated in a way to hold the impurities in a relatively stable suspension. In a test in which T.V.A. and the Kentucky Department of Agronomy co-operated, some of the material was successfully applied to eight acres with standard equipment ; there was no clogging of pipes, pumps, or nozzles, and no appreciable amount of sediment remained in the tank. The examples cited indicate the way in which T.V.A. research is constantly seeking to improve fertilisers through high concentration, improved physical and chemical characteristics and low final cost, with the results of the research passed on to industry.

A period of increased competition, ushered in by agricultural surpluses, lower farm prices and consequent slowing of the growth in demand for fertilisers, has moved much of the fertiliser industry to improve the character and effectiveness of fertilisers. As a result, industrial interest in T.V.A. developments of better products and processes and improved equipment continued at a high level. During the 1956 fiscal year, T.V.A. issued twenty-five royalty-free licences to fertiliser, chemical and equipment manufacturing companies for use of processes patented by the Authority. Outstanding in the trend toward improvement of products and processes in the fertiliser industry was the interest in high-analysis granular fertilisers, in which T.V.A. has done extensive work. The T.V.A. continuous ammoniator, or ammoniator granulator as it is more commonly called, has contributed significantly to the trend.

About 2,000,000 tons of granular fertiliser, much of it high or relatively high in plant nutrient content, was produced by the American industry during the year. It is estimated that two-thirds of it was made, using methods developed by the T.V.A. The continuous ammoniator, equipment that both large and small fertiliser producers can use, was developed in 1953 and was rapidly adopted after it was first demonstrated to the industry early in the 1954 fiscal year. In the 1956 fiscal year fifteen firms were licensed to use the process, and three additional firms were licensed to manufacture the ammoniator. Fifty-nine companies had been licensed to use or manufacture the ammoniator at the close of the fiscal year. Six firms were licensed to use or manufacture the T.V.A. cone mixer for producing superphosphate, making a total of twenty-three licences for this process. Other examples of the current use of T.V.A. developments included a large fertiliser company which installed in Florida a second rotating electric phosphorus furnace based on T.V.A. design. The company has a licence to use the T.V.A. by-product slag expansion process as well as the furnace design. By the end of the 1956 fiscal year, T.V.A. had granted a total of ninety-three licences for use of its chemical engineering developments. The licences for the use of T.V.A. processes and equipment are free and non-exclusive, the objective being to bring new developments into use as soon and as widely as possible.

Seven new patents on chemical engineering developments were obtained by T.V.A. during the year, bringing the total number to 110. Eleven additional patent applications were on file at the United States Patent Office. The patents issued this year included two on fertiliser ammoniation, one covering method and the other equipment. Another was for a process of making ammonium metaphosphate, a concentrated fertiliser now in an early stage of development. Others covered the rotating electric phosphorus furnace, a process for making carbonated nitric phosphate fertiliser, improvements in methods for crystallising ammonium nitrate, and an improved method for drying gases by contact with phosphoric acid.

SOIL TESTING MANUAL.—The unconfined compression test for cohesive soils is described in detail in a testing manual prepared by Soiltest, Inc., Chicago 39, Illinois, U.S.A. Standard engineering test procedures using laboratory equipment especially designed for performing the soil compression tests are outlined in the manual. The book deals with the interpretation, application and limitations of the test data obtained as well as with procedures and testing equipment.

Personal and Business

Appointments

MR. D. F. HARRISON has been appointed honorary secretary of Hull Chemical and Engineering Society.

POLLARD BEARINGS, Ltd., has announced the appointment of Mr. W. F. Clay as southern area sales manager.

MR. T. O. ORR has been appointed sales manager of Air Pumps, Ltd., 8, Francis Street, Westminster, S.W.1.

THE VAUGHAN CRANE COMPANY, Ltd., states that Mr. H. Hole, general works manager, has been appointed a director.

MR. E. J. CATCHPOLE has been appointed manager of the bonded structures division of Aero Research, Ltd., Duxford, Cambridge.

THE VILLIERS ENGINEERING COMPANY, Ltd., has announced that Mr. George A. Bower has been appointed a technical representative.

MR. T. S. DICKINSON, A.M.I.Mech.E., has been appointed chairman and managing director of the General Engineering Company (Radcliffe), Ltd.

JOHNSON, MATTHEY AND CO., Ltd., has announced the election of Mr. G. C. H. Matthey as chairman, following the recent death of Mr. H. W. P. Matthey.

MR. KENNETH N. DAVIS, a director of Radiation, Ltd., has been appointed chairman of the Council of Ironfoundry Association's training and education committee.

METAL INDUSTRIES, Ltd., has announced that the Right Hon. Lord Colyton has been appointed a director. Mr. J. T. Rymer has resigned from the board of directors.

E. K. COLE, Ltd., states that the board of directors of Ekco Plastics, Ltd., is as follows :—Mr. E. K. Cole, Mr. E. B. Willcocks, Mr. A. W. Martin and Mr. D. Radford.

ALFRED HOLT AND CO., Liverpool, has announced the appointment of Mr. J. B. Peacock, A.M.I.Mech.E., as chief superintendent engineer following the retirement of Mr. A. G. Arnold.

DR. RICHARD EVELYN DONOHUE BISHOP has been appointed to the Kennedy Chair of Mechanical Engineering, tenable at University College, University of London, from October 1, 1957.

DR. F. A. TATFORD, chief purchasing officer of the United Kingdom Atomic Energy Authority, has been appointed director of contracts in succession to Mr. R. A. Browning, who is to retire.

BURROUGHS ADDING MACHINE Ltd., has announced the appointment of Mr. A. Hurst as factory manager at Cumbernauld, Mr. W. Cleary at Strathleven, and Mr. F. Manning at Nottingham.

MR. M. J. J. RICHARDS has been appointed manager of the London branch sales office of the British Aluminium Company, Ltd., with effect from May 16, in succession to Mr. W. J. Allen, who is retiring from the company's service.

THE BRITISH TRANSPORT COMMISSION has announced that Mr. A. J. Pragnell, assistant commercial officer, British Road Services headquarters, has been appointed commercial officer, and will also act as commercial manager, B.R.S. (Contracts), Ltd.

BROOK MOTORS, Ltd., has announced that Mr. Brailsford Sykes, A.M.I.E.E., has been appointed manager of the Sheffield sales office in succession to Mr. Harold Gibson, who has retired. Mr. E. Nicholson has been appointed sales engineer at Sheffield.

JACK OLDING AND CO., Ltd., announces the following appointments :—Mr. J. D. Olding has been appointed president, and Mr. A. O. Bluth, chairman of the company ; Mr. R. J. Dudley has been appointed sales director, and Mr. A. F. Bacon service and parts director.

THE MINISTRY OF SUPPLY states that with the agreement of the Secretary of State for War, Major-General E. S. Lindsay has been appointed deputy controller of munitions in succession to Major-General G. N. Tuck. He will take up his duties on May 6.

MR. WALTER WEHTJE, managing director of the Atlas Copco Group, is to retire on April 13. He will be succeeded by Mr. Kurt Allan Belfrage, deputy managing director of the world group. Mr. John Harrison has been appointed managing director of Atlas Copco (New Zealand), Ltd.

THE PLESSEY COMPANY, Ltd., has announced the appointment of Dr. Denis Taylor, head of the electronics and instrument division at the Atomic Energy Research Establishment, Harwell, as director and general manager of Plessey Nucleonics, Ltd. He will also become research executive of the aircraft and electronics group of the Plessey Company, Ltd., and will be responsible for the co-ordination of the company's nuclear programme.

CABLE AND WIRELESS, Ltd., has announced the appointment of Mr. A. H. Harris, A.M.I.E.E., as deputy engineer-in-chief. He succeeds Mr. C. J. V. Lawson, M.I.E.E., M.I.R.E., who has been appointed engineer-in-chief in succession to Mr. J. A. Smale, M.I.E.E., who has retired after thirty-eight years' service with the company.

Business Announcements

TUNNY CRANES, Ltd., Everlode Place, Moreton-in-Marsh, Gloucester, has been formed to manufacture medium-capacity mobile cranes.

TUBE INVESTMENTS, Ltd., states that its subsidiary company, Mange Plastics, Ltd., will shortly open a new factory at Aston, Birmingham.

MR. C. C. G. ATKINSON, home sales manager of Gandy, Ltd., has relinquished his position in order to take up another appointment.

WILD-BARFIELD ELECTRIC FURNACES, Ltd., 147, Bath Street, Glasgow, C.2, states that its telephone number has been changed to City 4878.

GEORGE COHEN, SONS AND CO., Ltd., has been appointed sole world agents for the "Eldair" range of alligator shears made by Weldall and Assembly, Ltd.

THE NATIONAL COAL BOARD has announced the setting up of a reconstruction department in its North Eastern Division. Mr. G. C. Payne has been appointed reconstruction director.

ELLIOTT BROTHERS (LONDON), Ltd., states that it has concluded a licence agreement with the Industrial Instrument Corporation of Odessa, Texas, for the manufacture and sale of the I.I.C. differential pressure flowmeter in Great Britain.

THE UNITED STATES STEEL CORPORATION states that it has licensed the South African Iron and Steel Corporation (ISCOR), Pretoria, and de Wendel and Cie, S.A., Paris, France, to manufacture and sell "Cor-Ten" corrosion-resistant, high-strength, low-alloy steel.

JOHN AND E. STURGE, Ltd., has announced that it is extending certain production facilities at its Lifford Chemical Works, Birmingham, in order to increase its output of "Calofil," a special grade of precipitated calcium carbonate, used as a filler for polyesters.

CLARKSON (ENGINEERS), Ltd., Nuneaton, states that Clarkson Italiana S.p.A. is a new subsidiary company which has taken over the distribution of Clarkson "Autolock" and "Dedlock" milling chucks and cutters from Ratec S.R.L. The address of the new company is Via Rudolfo Farneti 10, Milan.

THE OWEN ORGANISATION has announced the formation of a new company, Rubery, Owen and Scott (S.A.), Ltd., 19–49, Scott Road, Congella, Durban, which will be responsible for the manufacture and marketing of certain of the Owen Organisation's products. Mr. A. G. B. Owen has been appointed chairman of the new company, Mr. E. W. B. Owen, vice-chairman, and Mr. J. Scott, managing director.

UDDEHOLM, Ltd., Somerset House, Temple Street, Birmingham, 2, announces the formation of a new mining and civil engineering division in this country. This new division will be under the charge of Mr. C. G. Midoup as general manager, and will be principally concerned with the sale of carbide rock drill steels which the parent company, Uddeholm Aktiebolag, has been making in Sweden for a number of years.

Contracts

THE NORTH BRITISH LOCOMOTIVE COMPANY, Ltd., Springburn, Glasgow, has received a contract from the British Transport Commission for five 300 h.p. diesel-hydraulic shunting locomotives. The locomotives are for use in the London Midland Region of British Railways.

THE ALUMINIUM WIRE AND CABLE COMPANY, Ltd., Swansea, has received an order for aluminium conductors to the value of over 2,000,000 dollars from the Quebec Hydro-Electric Commission in Canada. The conductors will be used for the 300kV transmission lines from Bersimis to Baie Comeau, and for the eastern part of the 300kV line from Bersimis to Montreal.

THE ENGLISH ELECTRIC COMPANY, Ltd., states that, following adjudication of various competing designs, it has received an order from the Admiralty for the design and manufacture of the main propelling steam turbines and condensers for Britain's first nuclear powered submarine. The order covers the prototype machinery, which will be tested in a land-based hull, and also the turbines to be installed in the first seagoing submarine.

THE STANTON IRONWORKS COMPANY, Ltd., near Nottingham, has secured an order from the Government of Venezuela for spun iron pipes, to a value of approximately 1,000,000 dollars. The pipes, ranging in diameter from 80mm to 750mm, will be used for extensions to the Caracas water system.

RICHARD COSTAIN, Ltd., has been awarded a contract for the removal of up to 10,000,000 cubic yards of peat, silt and sand at the Westfield (Fifeshire) opencast coal site. A 700-ton cutter suction dredger will be shipped by sea in sections and built on the site. The peat, silt and sand will be transported hydraulically through a 26in pipeline to an area specially prepared for it. A British manufactured 3000 h.p. engine will operate this unit. This is the first time this method will be used to clear overburden from an opencast coal site. Costains will be associated with Blankevoort and Zoon N.V. of Holland for the contract.

D. NAPIER AND SON, Ltd., has received a contract from the Engineer Research and Development Laboratories of the United States Army for a compressor set consisting of an eighteen-cylinder "Deltic" diesel engine and two Howden rotary positive displacement two-stage compressors, for use with a mobile liquid oxygen plant. The set, which is completely self-contained and weighs 43,000 lb, can be transported by road or by air ; when mounted on a road trailer it is approximately 8ft 10in by 11ft by 35ft overall, and has a gross weight of 50,000 lb. It will supply up to 30,000 lb of dry air per hour at 100 lb per square inch.

BRITISH INSULATED CALLENDER'S CABLES, Ltd., has received an order from the British Transport Commission for the supply and installation of telecommunication cables on the Crewe–Manchester line as part of the Railway Modernisation Programme. Both audio and carrier cables are included in the installation, together with distribution cabinets and trackside telephone cabinets. Because of the presence of a 25kV a.c. traction system running in close proximity to telephone cables throughout their length, it is necessary to provide heavy screening to keep the induced voltage on the cables within safe limits. B.I.C.C. has developed for this purpose special cables having aluminium sheaths of sufficient thickness to give a low longitudinal resistance, and provided with a multiple steel tape armour of selected material to raise the external sheath impedance. Deep driven earthing rods will provide earthing points of low resistance at regular intervals. To ensure that both the steel tapes and the aluminium sheath should be securely protected against corrosion, both from earth currents and local soil conditions because of their vital importance for screening purposes, special protective serving is applied over the steel tapes. It consists of P.V.C. and rubber sandwich, which the company introduced some time ago for use on power cables. The security of the protective serving is tested by applying a voltage of 10kV between the steel tapes and the coating of graphite with which the cable is finished ; a final test can therefore be made after the cables have been laid so that the state of the serving need not be in doubt.

Miscellanea

MACHINE TOOL TRADES ASSOCIATION.—The annual dinner of the Machine Tool Trades Association was held on March 20, at Grosvenor House in London. The toast of "The Guests" was proposed by the president, Mr. H. P. Potts. Both Sir Archibald Forbes, chairman of the Iron and Steel Board, who replied to this toast, and Mr. Halford Reddish, chairman of the Rugby Portland Cement Company, Ltd., who proposed the toast of "The Association," made references to taxation, capital investment and the like, having, no doubt, in mind the coming presentation of the Government's Budget. Mr. Robert Asquith, a past-president of the Association, replied to Mr. Reddish.

SEVENTY YEARS' CONTINUOUS SERVICE.—We are happy to record in these columns the fact that Mr. James Newson has just completed seventy years of continuous service with our printers, George Reveirs, Ltd. Now, at the age of eighty-three, he is going to work part-time. "Jimmy" Newson joined our printers in March, 1887, as a reading boy and a year later began a seven-year apprenticeship as a compositor. When that was completed, he continued hand-setting the type for the printing of this journal until 1911. The "Monotype" system was then installed and Mr. Newson was the first keyboard operator. He has been at it, without a break, ever since, and has thus been composing type for THE ENGINEER for seventy years. The congratulations which we offer to "Jimmy" on his outstanding achievement will, we feel sure, be shared by our readers who regularly see the results of his work.

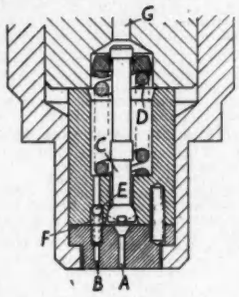
British Patent Specifications

When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. each.

INTERNAL COMBUSTION ENGINES

767,436. February 4, 1954.—FUEL INJECTION, Klockner-Humboldt-Deutz Aktiengesellschaft, Deutz-Mulheimerstrasse 149/155, Koln-Deutz, Germany. (*Inventor: Kurt Ziesche.*)

The invention relates to an internal combustion engine with an injection nozzle of the type having two jets differing in cross-section. The fuel injection nozzle shown in the drawing has a main fuel injection jet *A* and an initial fuel injection jet *B* of less diameter. A non-return valve *C*, loaded by a spring *D* is arranged in front of the jet *A* and a non-return valve in the form of a ball *E* loaded by a spring *F* is in front of the jet *B*. The springs and valves are so dimensioned that the valve *E* responds to a relatively low opening pressure, while the main valve *C* cannot respond until a pressure ten times as high is reached. The result of this dimensioning is that at low engine speeds, and also at starting, the valve *E* responds and the fuel is injected solely through the small jet *B* and thus well atomised. As the speed increases, the main injection jet *A* is positively rendered operative.



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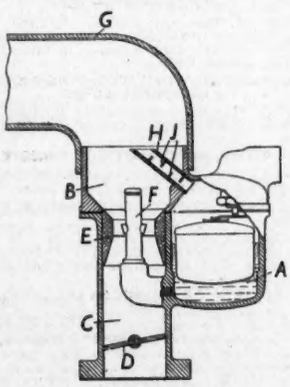
The fuel flows in uncontrolled manner to the two non-return valves, without being throttled, from a common supply pipe *G*. The ratio of the cross-section of the larger jet to that of the smaller jet is about half as great as the ratio of the highest engine speed to the lowest engine speed, for example, the starting speed. The fuel injection nozzle with the two jets terminating close together, so that equal conditions obtain in the combustion chamber with regard to the mixing of air and fuel in all states of operation of the engine, is also shown in the specification.—*February* 6, 1957.

769,648. May 10, 1955.—BALANCED CARBURETTORS, Solex, 190, Avenue de Neuilly, Neuilly-sur-Seine, France. (*Inventor: Andre Louis Mennesson.*)

The invention relates to balanced carburettors for internal combustion engines, the term "balanced" designating carburettors having a constant level fuel chamber, the upper part of which is connected with the main air intake of the carburettor through a passage which maintains in the constant level chamber a pressure substantially equal to that existing in the

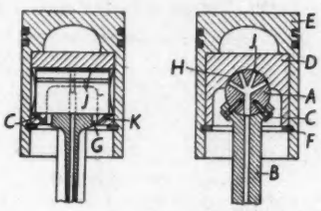


No. 769,648

air main intake. The general arrangement drawing shows that the carburettor includes a constant level fuel chamber *A*, a main air intake *B*, an induction pipe *C* with a throttle valve *D*, a venturi *E*, and a nozzle system *F*. In the construction shown by the drawing, a conduit *G* connects the main air intake *B* with an air filter and/or silencer but the invention is not limited to such an arrangement. A passage *H* is provided to balance the pressures in chamber *A* and in air intake *B*, respectively. The passage is provided with means preventing the flow of liquid fuel from the chamber towards the main air intake. In accordance with the invention, this means comprises a system of baffles *J* capable of deflecting the streams of any fluid (air or fuel) circulating through the passage while leaving free a sufficient section for the flow of air so that the desired balancing of the pressures is obtained. When the working conditions are such that, in the absence of partitions *J*, there would be a flow of fuel toward the main air intake *B*, the partitions are sufficient to prevent such a flow entirely.—*March* 13, 1957.

769,352. January 11, 1955.—A PISTON AND CONNECTING ROD ASSEMBLY, Klöckner-Humboldt-Deutz A.G., Deutz-Mulheimer Strasse 149/55, Köln-Deutz, Germany.

The invention relates to a piston and connecting rod assembly, particularly two-stroke fuel-injection internal combustion engines, in which the gudgeon pin is attached to the end of the connecting rod, and the bearing for the pin is a plain bearing in a pin mounting in the piston. The piston comprises a gudgeon pin *A* attached to the connecting rod *B* by screws *C*. A plain bearing for the pin is provided by a pin seating



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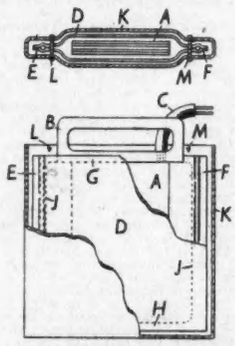
D, inserted into the piston body *E* from below and held by a spring ring *F*. In the piston the opposing surface *H* supporting the gudgeon pin is an uninterrupted light metal bearing surface. Grooves *J* for the feeding of lubricating oil are arranged in known manner in the gudgeon pin. The grooves extend parallel to the longitudinal axis of the gudgeon pin and lubricating oil is fed through a central passage in the connecting rod *B* and passages in the pin. A recess *G* is provided in the lower part of the gudgeon pin seating to allow the connecting rod to pass through and to move freely. On both sides of the gudgeon pin bearing passages *K* are brought through beyond the recess *G* for the return of the oil.—*March* 6, 1957.

ELECTRICAL ENGINEERING

769,413. April 28, 1954.—CONSTRUCTION OF SUBMERSIBLE ELECTRIC BATTERIES, Ultra Electric, Ltd., Western Avenue, Acton, London, W.3. (*Inventor: Dennis Rose.*)

The invention relates to electric batteries and more particularly to cells activated by immersion in sea-water, objects of the invention being to provide a construction which protects the cell from moisture and mechanical damage, with a construction that will comprise easy and rapid means for opening prior to immersion in the sea. Referring to the



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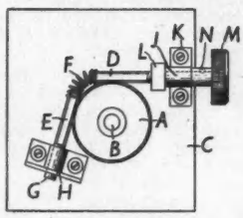
drawing, *A* is a battery, attached to the block *B*, which is shaped to form a handle. A cable *C* passes through the block and is connected to the plates of the battery. Around the battery is placed a bag *D*, made from two pieces of a flexible material which can be heat-sealed. The sealed edges *E* and *F* of the bag are stiffened by wires as shown. The bag *D* is sealed at the end *G* to the block and closed at the end *H*, air being exhausted from the bag immediately prior to the operation of sealing. The dotted line *J* shows the inner extent of the various areas of sealing around the bag. The bag containing the battery is enclosed in the shell *K*, which is provided with cutting blades *L* and *M*, so placed as to cut through unsealed portions of the bag during the withdrawal from the shell. In the modification of the invention shown in the specification, use is made of bag cutting means which can be operated without withdrawing the bag from the shell.—*March* 6, 1957.

POWER TRANSMISSION

769,901. June 29, 1955.—WORM GEARS, Philips Electrical Industries, Ltd., Spencer House, South Place, Finsbury, London, E.C.2.

The invention has for its object to provide a worm gear in which the backlash is small in both directions of rotation and which is simple and easy to manufacture. Referring to the drawing, *A* denotes a worm wheel mounted on a shaft *B* which is rotatable in a mounting plate *C*. Two worms *D* and *E* are meshed with the worm wheel *A*. These worms are connected together through a helical spring *F*. The shaft *G* of worm *E* is supported in a bearing *H* in which it is axially slidable. The worm *D* comprises a shaft *J* which is supported in a bearing *K* but is not



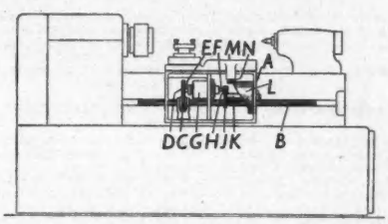
No. 769,901

slidable because of a collar *L* and a knob *M* secured by a set screw *N* on the shaft *J*. The helical spring is in tension and tends to draw the worms *D* and *E* together. Since, however, only the worm *E* is axially slidable, the two worm parts engage differently located sides of the teeth in a given sense of rotation of the worm wheel *A*. In this manner, backlash of the worms *D* and *E* relative to the worm wheel is removed, so that the wheel is immediately entrained on turning the knob *M* in either direction of rotation. Alternatively, the helical spring may be under compression so that it exerts a push force instead of a pulling force, but the operation of the transmission remains unchanged, as may be readily appreciated.—*March* 13, 1957.

MACHINE TOOLS

769,558. November 25, 1953.—DELAYED-ACTION CLUTCHES, Victor Salome and Clotaire Salome, both of 11–13, rue Lavoisier, Nanterre (Seine), France, and formerly of 24, rue Carnot, Le Pecq (Seine et Oise), France.

The invention relates to delayed-action clutches in metal-cutting machines such as lathes and similar machines. The machine illustrated in the drawing is an automatic thread-cutting machine similar to a



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lathe; it has a saddle *A* and a rotating splined shaft *B*. The saddle carries a toothed wheel *C* sliding on the shaft *B* and in mesh with a pinion *D* rigidly connected to a shaft *E* coaxial with a shaft *F*. The shaft *F* may be fixed for rotation with the shaft *E* by means of the clutch device *G*. The shaft *F* carries at its free end a pinion *H* in mesh with a wheel *J* keyed on to the shaft *K* of a cam *L* which controls the displacement of a carriage *M* sliding longitudinally on the saddle *A*, the cam *L* acting, as it rotates, on a roller *N* rigidly connected to the carriage *M* which is urged by suitable resilient means in such a manner that the roller *N* rests against the cam *L*. After disengagement, the clutch *G* permits re-engagement in such a position that the cam *L* retains the position in relation to the spindle which it would have had if there had been no disengagement; in other words, it is possible to disengage and re-engage as often as necessary without stopping the spindle, while retaining a correct longitudinal position for the carriage *M* on which the tool-holder is mounted. A complete description of the gearing is also given in the specification.—*March* 13, 1957.

Launches and Trial Trips

CRYSTAL DIAMOND, bulk sugar carrier; built by Hawthorn Leslie (Shipbuilders), Ltd., for the Sugar Line, Ltd.; length between perpendiculars 430ft, breadth moulded 61ft, depth moulded to upper deck 37ft 3in, draught 24ft 6½in, deadweight 9820 tons, service speed 12 knots; five holds, wing cargo spaces abreast Nos. 2, 3 and 4 holds, MacGregor steel hatch covers, one 25-ton, ten 10-ton derricks, steam winches; two 75kW diesel-driven generators, one 20kW steam-driven generator; Hawthorn-Doxford diaphragm oil engine, four cylinders, 600mm diameter by 2320mm combined stroke, 3300 b.h.p. at 108 r.p.m.—Launch, December 18.

TIGRE, cargo liner; built by the Chantiers Navals de la Ciotat for the Messageries Maritimes; length overall 488ft 4½in, length between perpendiculars 467ft 8in, breadth moulded 61ft 8in, depth to shelter deck 38ft 11in, draught loaded 25ft 7in, deadweight 8300 tons, displacement 14,079 tons, speed 16 knots, six passengers; three complete decks, seven watertight bulkheads, five holds, bale capacity 529,650 cubic feet, one 60-ton, one 30-ton, four 10-ton, ten 5-ton derricks, electric winches; three 250kW diesel-driven generators, one 30kW diesel-driven emergency generator; one Schneider-B. and W. single-acting, two-stroke diesel engine, 8300 h.p. at 115 r.p.m. Trial, November.

VIRGINIA, oil tanker; built by the Furness Shipbuilding Company, Ltd., for Nueva Vista Compania Naviera S.A., Panama; length between perpendiculars 525ft, breadth moulded 71ft, depth moulded 39ft 3in, deadweight 18,200 tons, trial speed 15½ knots; twenty-seven cargo oil tanks, one main cargo pump room, three 700 tons per hour turbine-driven centrifugal cargo pumps, three 150 tons per hour vertical stripping pumps; two 325kW turbine-driven generators, one 100kW diesel-driven generator; one set of Richardsons Westgarths double reduction geared turbines, 7300 s.h.p. at 100 propeller r.p.m., 8200 maximum s.h.p. at 104 r.p.m., two Foster Wheeler "D" boilers provide steam at 450 lb per square inch and 750 deg. Fah.—Launch, December 18.

HELISOMA, oil tanker; built at the Wallsend yard of Swan, Hunter and Wigham Richardson, Ltd., for Shell Tankers, Ltd.; length between perpendiculars 530ft, breadth moulded 69ft 3in, depth moulded 39ft, draught loaded 29ft 9¾in, load deadweight 18,220 tons, service speed 14½ knots; thirty-three cargo oil tanks, one main cargo pump room, four 400 tons per hour turbine-driven vertical centrifugal pumps, two stripping pumps, two 550kW turbine-driven alternators, one 200kW diesel-driven emergency alternator; one set of Wallsend Slipway double reduction geared turbines, 7500 service s.h.p. at 100 propeller r.p.m., 8250 maximum s.h.p. at 103 propeller r.p.m., two Babcock and Wilcox integral furnace water-tube boilers supply steam at 500 lb per square inch and 800 deg. Fah.—Trial, December 12.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

To-day, April 5.—LIVERPOOL BRANCH: Liverpool Engineering Society, 9, The Temple, 24, Dale Street, Liverpool, "Servicing the Automobile Electrical Equipment," 7.30 p.m.

Mon., April 8.—CENTRAL LONDON BRANCH: White Hall Hotel, Bloomsbury Square, London, W.C.1, "Rheostatic Controls of Oil Burners and Other Apparatus," S. O. Grant, 7.30 p.m. ★ N.W. LONDON BRANCH: Century Hotel, Forty Avenue, Wembley Park, "Electronics and Digital Computers," L. E. C. Hughes, 8.15 p.m. ★ YORK BRANCH: Royal Station Hotel, York, "Fire Alarm Systems," R. L. Moulson, 7.30 p.m.

Tues., April 9.—BOURNEMOUTH BRANCH: Grand Hotel, Firvale Road, Bournemouth, "Application of Electricity to Hospitals," 8 p.m.

Tues. to Sat., April 9 to 13.—Earls Court, London, S.W.5, Electrical Engineers (ASEE) Exhibition.

Wed., April 10.—BIRMINGHAM BRANCH: Birmingham Exchange and Engineering Centre, Stephenson Place, Birmingham, "Power Transformers," P. G. Sanderson, 7.15 p.m. ★ BRADFORD BRANCH: Midland Hotel, Bradford, "Wanderings with a Colour Film Camera," A. Spencer, 8 p.m.

Thurs., April 11.—SOUTHAMPTON BRANCH: Polygon Hotel, Southampton, "Radio Frequency Heating," P. B. Curtis, 8 p.m. ★ S.W. LONDON BRANCH: Prince of Wales Hotel, 2, Hartfield Road, Wimbledon, London, S.W.19, "In Search of Coal," W. H. Brooks, 7.30 p.m.

Fri., April 12.—BRISTOL AND W. OF ENGLAND BRANCH: Royal York House Hotel, Bath, "The Calder Hall Film," 8 p.m. ★ STOKE AND CREWE BRANCH: Royal Hotel, Crewe, "Electrical Fire Alarms," R. B. Whitehouse, 7.30 p.m.

BRITISH INSTITUTION OF RADIO ENGINEERS

Wed., April 10.—LONDON BRANCH: London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1, "The Uses of Electroplated Coatings in the Electronics Industry," R. W. Stobbs, 6.30 p.m. ★ N.E. SECTION: Institution of Mining and Mechanical Engineers, Neville Hall, Westgate Road, Newcastle upon Tyne, Film "Special Quality Valves," 6 p.m.

Thurs., April 11.—MERSEYSIDE SECTION: Chamber of Commerce, 1, Old Hall Street, Liverpool, "Electronics in Aircraft Installations," F. Ellson-Jones; and "A Negative Feedback Circuit for Magnetic C.R.T. Deflection," S. L. Fife, 6.45 p.m.

BRITISH INTERPLANETARY SOCIETY

Sat., April 6.—Caxton Hall, Caxton Street, London, S.W.1, "History of Rocket Development in the Walterwerke," Heinz Walder, 6 p.m.

CHEMICAL SOCIETY

Tues. to Fri., April 9 to 12.—Anniversary Meetings, 1957, at Cambridge.

ILLUMINATING ENGINEERING SOCIETY

Mon., April 8.—SHEFFIELD CENTRE: Medical Library, the University, Western Bank, Sheffield, "Lighting at London Airport," J. G. Holmes, 6.30 p.m.

Tues., April 9.—LONDON CENTRE: Lighting Service Bureau, 2, Savoy Hill, London, W.C.2, "Aviation Ground Lighting," E. S. Calvert, 6 p.m.

Thurs., April 11.—MANCHESTER CENTRE: N.W. Electricity Board, Town Hall, Manchester, Annual General Meeting, 5 p.m.

INCORPORATED PLANT ENGINEERS

Mon., April 8.—DUNDEE BRANCH: Mathers Hotel, Dundee, "The Problems of Textile Research," H. Corteen, 7.30 p.m.

Tues., April 9.—MANCHESTER BRANCH: Engineers' Club, Albert Square, Manchester, "Practical Fundamentals of Electricity," H. L. Buxton, 7.15 p.m.

Wed., April 10.—LEICESTER BRANCH: Leicester College of Art and Technology, Leicester, "Factory Lighting," A. Holden, 7 p.m.

Thurs., April 11.—GLASGOW BRANCH: Scottish Building Centre, 425, Sauchiehall Street, Glasgow, "Applications of Photography in Industry," A. Horder, 7.15 p.m. ★ MERSEYSIDE AND N. WALES BRANCH: Exchange Hotel, Liverpool, "Engineering in the Making of Refractories," E. Snodgrass, 7.15 p.m. ★ PETERBOROUGH BRANCH: White Lion Hotel, Church Street, Peterborough, "Workshop Maintenance at a U.S.A.F. Base in England," 7.30 p.m.

INSTITUTE OF FUEL

Wed., April 10.—LONDON BRANCH: Institution of Civil Engineers, Great George Street, Westminster, London, S.W.1, "Koppers-Totzek Gasification Process," Hans Koppers, 5.30 p.m.

INSTITUTE OF MARINE ENGINEERS

Mon., April 8.—JUNIOR LECTURE: Woolwich Polytechnic, London, S.E.18, "Gas Turbines," J. A. Barnes, 7 p.m.

Tues., April 9.—Joint meeting with the Institution of Naval Architects, 85, Minories, London, E.C.3, "The Design and Operating Experience of an Ore Carrier Built Abroad," R. Atkinson, 5.30 p.m.

Wed., April 10.—MERSEYSIDE AND N.W. SECTION: Riversdale Technical College, Liverpool, "Modern Marine Steam Turbines," J. H. Gooch, 5.30 p.m.

INSTITUTE OF PHYSICS

To-day and Sat., April 5 to 6.—X-RAY ANALYSIS GROUP: Physics Department, University College, Cardiff, Spring Conference, "Minerals and Inorganic Compounds."

Tues. to Thurs., April 9 to 11.—STRESS ANALYSIS GROUP: University College, Leicester, Group Annual Conference.

Fri., April 12.—LIVERPOOL AND N. WALES BRANCH: Denbighshire New Technical College, Wrexham, "The Industrial Utilisation of Radiation," R. Roberts, 7 p.m. ★ NON-DESTRUCTIVE TESTING GROUP: 47, Belgrave Square, London, S.W.1, "Damping Capacity and Fatigue," K. M. Entwhistle, 6.30 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Tues., April 9.—MIDLANDS CENTRE: Birmingham Exchange and Engineering Centre, Stephenson Place, Birmingham, Annual General Meeting, 7.30 p.m.

Thurs., April 11.—LONDON CENTRE: Royal Society of Arts, John Adam Street, London, W.C.2, "Wear and Tear," J. Johnson, 6.30 p.m.

INSTITUTION OF BRITISH AGRICULTURAL ENGINEERS

Mon., April 8.—W. CENTRE: Electricity House, Bristol, "Silage-making Techniques," R. M. Chambers, T. P. Gregory and R. J. Orford, 7.15 p.m.

Tues., April 9.—LONDON CENTRE: 6, Buckingham Gate, London, S.W.1, "Recent Developments in Tractor Testing Techniques at the N.I.A.E.," T. C. D. Manby, 5 p.m.

INSTITUTION OF CHEMICAL ENGINEERS

Tues. to Thurs., April 9 to 11.—MIDLANDS BRANCH: The University, Edgbaston, Birmingham, Symposium on "Chemical Engineering Education."

INSTITUTION OF CIVIL ENGINEERS

Tues., April 9.—HYDRAULICS (B) MEETING: Great George Street, Westminster, London, S.W.1, "Control of Flow by Gates and Valves," H. D. Morgan, 5.30 p.m.

Wed., April 10.—HULL AND E. RIDING BRANCH: Electricity Showroom, Ferensway, Hull, Annual General Meeting, followed by "Apapa Wharf," D. C. Coode, 6.15 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Mon., April 8.—N.E. CENTRE: Royal Station Hotel, Newcastle upon Tyne, Annual General Meeting and Conversazione, 6.15 p.m.

Tues., April 9.—MEASUREMENT AND CONTROL SECTION: Savoy Place, London, W.C.2, "A Deep Electrolytic Tank for the Solution of Two and Three-Dimensional Field Problems in Engineering," E. R. Hartill, J. G. McQueen and P. N. Robson, 5.30 p.m. ★ N.W. CENTRE: Free Trade Hall, Manchester, "Nuclear Energy in the Service of Man," T. E. Allibone, 7 p.m. ★ N. IRELAND CENTRE: Engineering Department, Queen's University, Belfast, "Age and the Incidence of Fires in Electrical Installations," L. Gosland, 6.30 p.m.

Wed., April 10.—RADIO AND TELECOMMUNICATION SECTION: Savoy Place, London, W.C.2, "The Remote and Automatic Control of Semi-attended Broadcasting Transmitters," R. T. B. Wynn and F. A. Peachey, 5.30 p.m. ★ S.W. SCOTLAND SUB-CENTRE: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Temperature Rises in Electrical Machines on Variable Load and with Variable Speed," A. Tustin and J. J. Bates, 7 p.m. ★ N.W. SUPPLY GROUP: Engineers' Club, Albert Square, Manchester, "Mechanical Strength of Power Transformers in Service," E. T. Norris, 6.15 p.m. ★ N. LANCASHIRE SUB-CENTRE: N.W. Electricity Board, Jubilee Street, Blackburn, "Electrical Energy from the Wind," E. W. Golding, 7.15 p.m. ★ N. SCOTLAND SUB-CENTRE: Robert Gordon's Technical College, Aberdeen, "Nuclear Reactors and Power Supply," G. W. K. Ford, 7.30 p.m. ★ MERSEY AND N. WALES CENTRE: Philharmonic Hall, Liverpool, "Nuclear Energy in the Service of Man," T. E. Allibone, 6.30 p.m.

Thurs., April 11.—UTILISATION SECTION: Savoy Place, London, W.C.2, "Development of Transportable Thermal Storage Space Heaters," E. Bates; and "Electrical Floor Warming," J. W. Moule and W. M. Stevenson, 5.30 p.m. ★ N. SCOTLAND SUB-CENTRE: Caledonian Hotel, Dundee, "Nuclear Reactors and Power Supply," G. W. K. Ford, 7.30 p.m. ★ N. MIDLAND CENTRE: Yorkshire Electricity Board, Ferensway, Hull, "Highland Water Power—the Developments of the North of Scotland Hydro-Electric Board," 7.15 p.m.

INSTITUTION OF ENGINEERING DESIGNERS

Mon., April 8.—N.E. BRANCH: Northern Architectural Association Hall, 6, Higham Place, Newcastle upon Tyne, "Materials and Processes in Atomic Energy," R. Parsons and P. J. Booker, 7.15 p.m.

INSTITUTION OF ENGINEERS IN CHARGE

Wed., April 10.—St. Bride Institute, Bride Lane, Fleet Street, London, E.C.4, "Methods of Controlling the Corrosion of Metals," F. Wormwell, 6 p.m.

INSTITUTION OF HEATING AND VENTILATING ENGINEERS

Tues., April 9.—LIVERPOOL AND DISTRICT BRANCH: College of Buildings, Clarence Street, Liverpool, Annual General Meeting, 6.30 p.m.

Fri., April 12.—MANCHESTER AND DISTRICT BRANCH: County Offices, Preston, "Modern Methods of Oil Firing," 6.30 p.m.

INSTITUTION OF HIGHWAY ENGINEERS

To-day, April 5.—Institution of Structural Engineers, 11, Upper Belgrave Street, London, S.W.1, "The Improvement of Traffic Flow in Urban Areas," S. Green, 5.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, April 5.—GENERAL MEETING IN CONJUNCTION WITH THE HYDRAULICS GROUP: 1, Birdcage Walk, Westminster, London, S.W.1, "Modern Trends in Waterworks Pumping Machinery," T. Irvine Hudson, 6 p.m.

Tues., April 9.—AUTOMOBILE DIVISION GENERAL MEETING: 1, Birdcage Walk, Westminster, London, S.W.1, Symposium on "Superchargers and Supercharging," 4.30 p.m. ★ N.W. A.D. CENTRE: Leyland Motors, Ltd., Leyland, Lancs, "Transmission Development for Public Service and Heavy Goods Vehicles," A. Gordon Wilson, 7.15 p.m.

Wed., April 10.—LUBRICATION GROUP: 1, Birdcage Walk, Westminster, London, S.W.1, Discussion on "Standardisation of Lubricants," 6.45 p.m. ★ MIDLAND GRADUATE SECTION: James Watt Memorial Institute, Great Charles Street, Birmingham, Annual Joint Meeting with the local Graduates' Sections of the Institutions of Civil and of Electrical Engineers, "Irradiation of Materials," Dr. Charlesby and W. H. Davieson, 6.45 p.m. ★ SCOTTISH GRADUATE SECTION: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, Informal Lecture on "Nuclear Energy," A. T. Bowden, 7.30 p.m. ★ YORKSHIRE GRADUATE SECTION: Visit to Salts (Saltaire), Ltd., Saltaire, 2 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

Mon., April 8.—HALIFAX AND HUDDERSFIELD GRADUATE SECTION: Huddersfield Technical College, Huddersfield, "Production of Machine Tool Castings," G. W. Nicholls, 7.30 p.m.

Tues., April 9.—BIRMINGHAM GRADUATE SECTION: James Watt Memorial Institute, Great Charles Street, Birmingham, "Lock Design and Manufacture," C. G. Smith, 7 p.m.

Wed., April 10.—LONDON GRADUATE SECTION: 10, Chesterfield Street, London, W.1, "Problems Associated with the Planning of a New Factory," E. G. Cash, 7.15 p.m.

Thurs., April 11.—ROCHESTER SECTION: Prince of Wales Hotel, Chatham, Annual General Meeting, 7 p.m.

INSTITUTION OF THE RUBBER INDUSTRY

To-day, April 5.—N.E. SECTION: Eldon Grill, Grey Street, Newcastle, Annual General Meeting, 7 p.m.

Mon., April 8.—S. WALES AND MONMOUTHSHIRE SECTION: Angel Hotel, Cardiff, Annual General Meeting, 7.30 p.m. ★ PRESTON SECTION: Bull and Royal Hotel, Church Street, Preston, Annual General Meeting, 7.15 p.m. ★ MIDLAND SECTION: Goodyear Tyre and Rubber Company (G.B.), Ltd., Wolverhampton, "Building a Rubber Factory," S. Bentley, 6.45 p.m.

Tues., April 9.—LONDON SECTION: Royal Society of Tropical Medicine and Hygiene, 26, Portland Place, London, W.1, Annual General Meeting, 6.30 p.m. ★ SCOTTISH SECTION: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, Annual General Meeting, 7 p.m.

Wed., April 10.—S. SECTION: Polygon Hotel, Southampton, Annual General Meeting, 7.30 p.m. ★ W. OF ENGLAND SECTION: Melksham House, Melksham, "Development in Rubber Machinery," E. Morris, 7.45 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

Thurs., April 11.—W. COUNTIES BRANCH: University of Bristol, Joint Meeting with the Institution of Civil Engineers, "Some Methods of Extending the Life of Bridges by Repair and Strengthening," J. D. West, 8 p.m.

Fri., April 12.—MIDLAND COUNTIES GRADUATES' AND STUDENTS' SECTION: Birmingham Exchange and Engineering Centre, Birmingham, Chairman's Address, F. J. Pardoe, 6.30 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, April 5.—Pepys House, 14, Rochester Row, Westminster, London, S.W.1, Film Evening, 7 p.m.

Mon., April 8.—SHEFFIELD AND DISTRICT SECTION: Livesey Clegg House (opposite Union Street Cinema), Sheffield, "Experience of the Monte Carlo Rally," T. C. Harrison, 7.30 p.m.

Fri., April 12.—ORDINARY MEETING: Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "Electric Locomotive Design," F. J. G. Haut, 7 p.m.

LIVERPOOL METALLURGICAL SOCIETY

Thurs., April 11.—Liverpool Engineering Society, The Temple, 24, Dale Street, Liverpool, "Vacuum Techniques in Metallurgy," M. Harper, 7 p.m.

MANCHESTER GEOLOGICAL AND MINING SOCIETY

Thurs., April 11.—Wigan and District Mining and Technical College, Wigan, "Underground Haulage Costs," J. C. R. Clapham, 3.15 p.m.

NEWCOMEN SOCIETY

Wed., April 10.—ORDINARY GENERAL MEETING: Lecture Theatre, Science Museum, South Kensington, London, S.W.7, Presidential Address, "Observations on the History of Water Power," A. Stowers, 5.30 p.m.

NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

Fri., April 12.—Lecture Theatre, Mining Institute, Newcastle upon Tyne, "Marine Machinery Breakdowns," J. H. Milton, 6.15 p.m.

ROYAL AERONAUTICAL SOCIETY

Tues., April 9.—SECTION LECTURE: 4, Hamilton Place, London, W.1, "Fail-Safe Structural Design," N. F. Harpur, 7 p.m.

ROYAL INSTITUTION OF CHARTERED SURVEYORS

Thurs., April 11.—LAND SURVEYORS' GENERAL MEETING: 12, Great George Street, Westminster, London, S.W.1, a Symposium on "The Application of Electronic Computing to Land Surveying," R. C. A. Edge, P. H. Kenney and Miss M. L. Windsor, 5.45 p.m.

SOCIETY OF CHEMICAL INDUSTRY

Mon., April 8.—CORROSION GROUP SPRING LECTURE: 14, Belgrave Square, London, S.W.1, "Recent Research at Milan on the Electrochemistry of Corrosion," R. Piontelli, 6.30 p.m.

Mon. to Tues., April 8 to 9.—CHEMICAL ENGINEERING GROUP: 14, Belgrave Square, London, S.W.1, Symposium on "Safety."

Thurs., April 11.—ROAD AND BUILDING MATERIALS GROUP: 14, Belgrave Square, London, S.W.1, Annual General Meeting, 6 p.m.

WEST OF SCOTLAND IRON AND STEEL INSTITUTE

Fri., April 12.—39, Elmbank Crescent, Glasgow, Annual General Meeting, followed by "Continuous Casting," J. R. Rippon, 6.45 p.m.

WOMEN'S ENGINEERING SOCIETY

To-day, April 5.—LONDON BRANCH: Hope House, 45, Great Peter Street, London, S.W.1, "The Use of Electronic Computers in Engineering," Miss Jill Robinson, 7 p.m.